The Care of the Body

Woodworth

CARE OF THE BODY

THE MACMILLAN COMPANY
NEW YORK · BOSTON · CHICAGO
ATLANTA · SAN FRANCISCO

MACMILLAN & CO., LIMITED
LONDON · BOMBAY · CALCUTTA
MELBOURNE

THE MACMILLAN CO. OF CANADA, LTD.
TORONTO

THE CARE OF THE BODY

BY

R. S. WOODWORTH

PROFESSOR IN COLUMBIA UNIVERSITY

New York

THE MACMILLAN COMPANY

1912

5

A.278656

Set up and electrotyped. Published September, 1912

Set up and electrotyped by
The Mason-Henry Press, Syracuse, N. Y.

PREFACE

This book is intended chiefly for the young man, and is founded on the belief that an intelligent man, without technical knowledge of medicine, and without excessive attention to the care of his health, can still do much to keep himself in good condition. An intelligent man will desire to understand the reasons for his actions, and will demand some information regarding the processes of the body as a basis for undertaking the management of his health. Accordingly the book enters, not too deeply, into some of the important topics of physiology, but, not wishing to stray far from the practical, it makes no effort to be complete on the scientific side. It is a book on hygiene. Of the two great divisions of this subject, it is concerned almost entirely with what is called personal hygiene, though it contains a few allusions to the importance of public hygiene, the most promising science of the times. Public hygiene is the concern of the specialist, though the good citizen should be aware of its

importance. But personal hygiene is the direct concern of every man, since he must be his own manager in matters of food and sleep, exercise and recreation, and other daily activities which are influential in determining the difference between good health and mediocre health.

CONTENTS

CARE OF THE BODY

CHAPTER I

THE SCIENCE OF HEALTH

Our age is marked by a wonderful increase in the application of science to practical affairs, and it is marked also by a growing recognition of the value of health. Many societies and movements have for their object the preservation and improvement of health, but most of these movements are disappointing, because they are based on fads and speculations, rather than on genuine scientific knowledge. A true science of health, based on investigation of the workings of the body in health as well as in disease, would be the most practical and useful of all the applications of science.

Scientific care of the body's health—it is a noble motto, but may raise a spirit of objection. For often the healthiest persons appear to take no special care for their health; and the body seems to be equipped to take care of itself without interference from the side of thought or science. Peasants and primitive races, completely innocent of the sciences, seem to be

among the healthiest of men; and, at the other extreme, the hygienic crank, who is all the time considering the state of his health, is a very poor model of healthy living.

This objection thrown at us at the outset of our study contains on the whole more truth than error. Certainly the crank on the subject of health is a poor example to follow. Constant thought about one's condition is an unhealthy practice, and that for a very clear reason. Worry about one's health, or for that matter, about anything else, is one of the most wearing conditions that afflict us. Worry turns a man, for the time being, into a sort of monomaniac. It fastens on him a "fixed idea," an oppressive impulse that takes possession of him, and indirectly gets hold of his bodily activities and demoralizes them. This is an action of the mind on the body—one of those actions of which so many examples occur in medical practice. Just as digestion is best when surroundings are agreeable and food well-tasting, and when the "heart" is light and free from care, so all the organs do their best when the dominant note is cheerfulness. A man may be hypnotized by his own worry, and become sick because he believes himself sick.

The doctors know this fact well, and apply it

in their practice. To gain the confidence of the patient, to remove worry and induce hopefulness, is often half the battle. Quack healers base their treatment on this power of suggestion. The mind-curists and faith-healers and Christian Scientists have got hold of the same law and built it up into a system. Probably all of the success that they have—and they are undeniably successful in certain types of disease—comes from the power of suggestion. Fortunately, the hard-headed man does not need to abandon his good sense and follow these people into all their metaphysical vagaries and all their foolish denials of proved facts, nor submerge himself in the study of occultism, in order to gain the benefits of the principle involved. A cheerful disposition, a refusal to worry, do the same thing for many a man, and do it better.

If there is any reader, then, who is likely to turn the study of the laws of health into a source of anxiety and fussiness, here is the point at which he should lay this book aside, for he will get more harm than good from it. But scientific hygiene has nothing in common with worry. It tries rather to put a man where he can know what he is about, and so need not worry. It aims to supply knowledge that can be calmly

and confidently applied to the regimen of life.

But even yet we have not squarely met the objection that confronted us at the start. When we call to mind those healthy peasants, living in blissful ignorance of anatomy, physiology, and bacteriology, and guided only by their hygienic instincts, we tend to doubt the value of even the calmest and most unworried knowledge of bodily functions. But we must remember that we are unwilling to lead the simple life of primitive folk. We refuse to be guided simply by the plain animal instincts. We crowd ourselves into cities, we strive after success and progress, we like exciting amusements, we live in artificial conditions for which the natural instincts are not adequate.

It is not the ignorance of the peasants that keeps them healthy, it is their out-door life, plain food, regular habits, freedom from dust and contagion, from eye strain and mental strain. We cannot hope to be primitive, even if we would. As a matter of fact, we have to live under complex and artificial conditions, and must learn to make the best of them. It is not certain that these modern conditions are necessarily unhealthy. What is certain is that they call for something more than the plain animal instincts.

It is all right to follow the intuitive light of nature out among the woods and mountains, but it wouldn't do in a dynamo room. One of the most stringent rules for him who would keep his health is not to touch a live wire—but it is a rule not provided by instinct. It depends on knowledge. There are dozens of rules of a similar character that must be followed but are not instinctive. Some of them are not absolutely stringent; they may be disobeyed without instant death, but bad effects follow sooner or later. Some of them everybody learns, but of others many are ignorant. If everyone were a good observer of cause and effect, more of these hygienic rules would be in general use. As it is, thousands of people do the most insanitary things, and suffer the consequences, without ever guessing the cause of their troubles.

The prevalence of fads and nostrums, medicines and peculiar modes of living, guaranteed by their advocates to lead to health, is evidence of the need of a science of health, These fads and nostrums are thoroughly unscientific, by which is meant that they are not based on a thorough study of the facts and laws of the body's workings. Many are based on half-truths, many on ingenious speculations or "happy thoughts,"

which, instead of being first put to a scientific test, are at once taken up as if they were divine revelation. Many such fads, again, are based on observation, but on observation of a rough and partial sort. Even physicians are sometimes guilty of giving forth rules of health that are based on a few chance observations. They come out in the papers with some new rule which has been suggested to them, probably, by their experience with a few of their patients, but which is not based on a real knowledge of cause and effect, and such rules are pretty sure to break down when given a wider trial. One favorite method of reaching such rules is to start by assuming—what is by no means altogether true—that civilized conditions of life are unhealthy and savage conditions healthy, and then to ask what is the great difference between the two conditions. Civilized and savage ways of living differ in so many respects that a variety of answers are suggested. Savages wear few clothes; and so it has been argued that the way of health is to get rid of clothing as far as possible. Savages take few baths; and one doctor is reported to have argued that it is the bathing so prevalent in civilized communities that wrecks our health. A dozen other rules, as well-based as these, could

be found by this method; but none of them would rest on any real knowledge of cause and effect. In so far as the savage is more healthy than the civilized man, it would be much safer to attribute this difference partly to the outdoor life of the savage, and even more, perhaps, to the fact that the weaker members of a savage community are not so protected from disease and hardship as are the weaker members of the civilized community, and therefore die off, leaving the living population with a better average native constitution than would be the case without this severe process of natural selection. The absence of severe natural elimination of the unfit from civilized societies is a matter which is beginning to cause concern to those who take a broad view of the problems of civilization; but it does not concern us here, for here we are concerned not with public hygiene or eugenics, but with the individual's care of his own health.

A true science of health must be based on an understanding of cause and effect. It would not be possible to reduce it to a set of categorical rules to be followed blindly. Though the human body may rightly be regarded as an elaborate piece of machinery, running according to definite laws, yet it is so intricate, so flexible, so

adaptable, so subject to variations with variations of the conditions, that any blind following of rules is pretty sure to go astray. The thing to be gained by such a study as is here proposed is an intelligent understanding of the body that shall lead one to treat it rationally. The practical rules should be linked up with knowledge of their basis in the laws of physiology and the other sciences that deal with the body.

There is a certain danger in rules, and in preaching ardently for this or that essential of healthy living; we may fail to take due account of the existing habits of the individual at whom we preach. We may incite him to do what he is already overdoing or caution him against what he is already over-avoiding. We perhaps urge on him the need of exercise when he is already an athletic enthusiast; or we endeavor to impress on him the importance of a carefully selected diet, when he is already eating by weight and measure and in terms of chemistry. Rules are always dangerous without the principles on which they are based, and without sufficient flexibility to allow for varying conditions.

If there is any one general rule which is useful in the care of health—call it principle, rather —it is to avoid excesses. Avoid excessive drink-

ing, avoid excessive eating, avoid too much excitement, too much exercise, too much work, too much sleep, too much of anything. Most of the things that do us harm do so because they are taken in excess. We seem to have a native proneness to overwork a good thing. Even food, from the excess with which it is often eaten, has to be counted among the causes of human ailments. Nothing in excess—an old Greek maxim—is then as good a general rule as hygiene can give. Yet even this is dangerous advice to give at random. Some persons need rather to be cautioned against *excessive moderation.* Vigorous activity, so far from injuring the healthy body, is natural to it, and has a tonic effect on all the vital functions. Where the line should be drawn between excess and the proper measure—that cannot be told in a general rule. What is moderate for one person is excessive for another. Most excesses betray themselves by certain symptoms, such as fullness and colic after over-eating, persistent fatigue after too much exercise, sleeplessness or high nervous tension after too much excitement or mental work. By observing these symptoms and tracing them back to their causes, a man can come to learn his own measure.

CHAPTER II

THE BLOOD

Among the many sorts of activity that go to make up the life of the body, none is more necessary than the circulation of the blood. "The blood is the life," runs an old saying. The physician, to discover whether life has finally departed from the body, examines whether the heart is still beating; and the heart certainly seems to be, more than any other part, the very seat of life.

It is true that, on closer study, the heart is found not to be the peculiar seat of life, and the blood is scarcely entitled to be called living. The blood does not contain the life of the body, but is, rather, food for the living organs; and the heart is simply a pump keeping the blood moving. The life of the body is not concentrated in any one part, but resides in the *cells* of the muscles, the glands, the brain, and all the organs. If one wishes to discover the secret of life, one must penetrate the inner mysteries of these microscopic cells. Each little cell has its life, and the com-

bination of all these little lives is, in some sense, the life of the body.

But if we are not seeking to fathom the mystery of life, but are simply taking the body as a whole and considering what keeps it alive, then nothing is more essential than the blood and its motion through the arteries and veins.

It is often easier to understand the working of large things than the working of smaller things; for example, most of us probably have a clearer idea of the use of railroads and canals to a country than of the body's need for the circulation of the blood. We understand perfectly well that without railroads or some other means of transportation, different sections of a country would be of no use to each other. The North could not use the South's cotton, nor the East the grain from the West. The mills of the East would do the West no good; the fish from the coast would not pass inland. Most sections would still have to burn wood, though coal were abundant elsewhere. Every small district would have to supply all its own needs, and it could usually do this only in a crude and primitive way. There would be no chance for any part of the country, by specializing, to develop its own special resources to their full extent.

Though so much smaller in bulk, the human body compares very favorably with a nation in point of complicated organization. If the cells of the body are compared to the individuals composing a nation, then the body is more populous than any nation on earth. There are more cells living together in the body than there are inhabitants of China, oh! many times more. The cells differ in their powers, some performing one kind of work and some another; and the "division of labor" among them goes so far that the muscle cell cannot perform the duties of the nerve cell, nor the gland cell those of the bone cell. Each does its particular work and can do no other. Unless there were some system of transportation between the different parts and organs, one would be of no service to another, and every part would perish for lack of that which some other part could supply.

The body has two systems of communication between its various parts; one system consisting of the nerves and the other of the blood vessels. The nerves, much like telegraph and telephone lines, carry messages from one place to another. The blood vessels, like the railroads, carry materials, and distribute the products of each part to all the rest. The circulation resembles the

freight service of the railroads; and there is nothing in the body corresponding to the passenger service, for the cells are not free to move about. They cannot go after what they want, but must have it brought to them. More than the railroads do is done by the circulation, for it provides the water supply, and the sewage system. *Whatever needs to be moved,* whether supplies that are needed or waste that must be removed, it all passes by the same channels. The circulation has a monopoly of all that sort of business.

In its use, then, the circulation is much like the railroads of a country; but in its manner of working it is far different. No consignments of goods here, boxed and labelled and carefully delivered to the right party. Whatever materials any organ produces, it dumps into the blood stream, and whatever any organ needs it must take from the stream as it flows by. Food from the stomach, oxygen from the lungs, medicinal substances that are manufactured in small quantities by several organs, all are mingled and blended together with the sewage or wastes from all the organs, and the astounding mixture flows constantly through every quarter of the body. Out of this stream, as it flows by, the muscles

take up their fuel, the lungs and kidneys pick out the wastes, and the liver, like a thrifty merchant, takes up and stores away almost anything good that happens to be abundant at the time. Out of the blood, too, every cell takes the food by which it grows. The blood brings it nourishment in its youth, medicine in its sickness, energy for its activity, restoratives in its times of rest, till finally the blood saturates it with poisons and kills it. What the Nile is to Egypt, and much more, the blood stream is to every organ of the body.

The quantity of blood is about 5 or 7 per cent of the total weight of the body, so that a man weighing 150 pounds contains 8 to 10 pounds of blood. The blood is composed in largest measure of water, about four-fifths of it being water. This large proportion of water is needed, first of all, to make the blood an easily flowing liquid. The water is the medium in which all the other ingredients are carried. Besides that, water is a food, as necessary as any other. All living cells are composed largely of water; all living substance is semi-fluid, life being a process that cannot go on in a dry state, but only in a liquid or semifluid. The water in the blood therefore serves the double purpose of

making a stream in the blood vessels, and of passing out from the vessels into the cells for their use.

The foods and the wastes in the blood are dissolved in the water, and in this fluid condition flow easily through the blood vessels, and even pass out through the walls of the vessels to the cells of the several organs. The foods enter the blood from the digestive organs—the stomach and more especially the intestines—and circulate through all the organs. The wastes pass out of all the organs into the blood, and are taken up out of the blood by the excretory organs, such as the kidneys. Leaving to later chapters a fuller account of the foods and of the wastes, we shall here notice some remarkable facts regarding the blood as a whole.

One of the remarkable facts is the uniform composition of the blood. In health, not only does it always contain the same ingredients, but they are always, within very narrow limits, in the same proportions. Water, for example, remains always in about the proportion of four-fifths. When much water has been taken into the stomach, it passes quickly into the blood, but from the blood it promptly passes out into the tissues, and it also is taken out rapidly by the kidneys and

sweat glands, so that, very soon, the proportion of water in the blood is back at its usual four-fifths. When, on the other hand, water has been lost rapidly from the body, as in profuse perspiration, the blood sucks water out of the tissues throughout the body and maintains very nearly the usual proportion; and this drawing of water out of the tissues creates the sensation of thirst, and so leads to the drinking of more water to replenish the body's supply. It is much the same with other ingredients of the blood. For example, one of the foods always present in the blood is sugar; it is present in small proportion, only 10 to 15 parts per thousand, but it is always there in about this proportion. When much sugar is taken into the blood from the food in the intestines, it is promptly taken out and stored by the liver; but when the muscles, which burn sugar for fuel, have taken so much out of the blood as to lower the proportion below the normal, then the blood sucks the sugar again out of the liver. It may happen, in long fasting, that all the sugar is gone from the liver; but in that case the blood still gets sugar from some source, probably from inactive muscles, and passes it along to any muscles that chance to be active. Other foods, known as fat and protein, on being absorbed

from the intestine, are treated in much the same way. Instead of accumulating in the blood after a meal, they are taken out and stored by the liver, by the muscles, and by the fat-stores beneath the skin and in many other locations. The blood retains a certain proportion of each of these foods and gradually gives up what it contains to active or growing organs; but as fast as it gives up, it makes good its loss from the liver or other stores. So it is, again, with waste substances. The blood always contains a certain small proportion of each waste substance; but if more enters the blood from any organ, the lungs or kidneys promptly remove the excess, and the amount in the blood is scarcely altered. This uniformity of the blood is important for the life of the cells.

Besides water, foods and wastes, the blood contains many other substances. For one thing, it contains salts, such as the common salt or sodium chloride of our tables. These salts are, in strictness, foods, for all living cells contain salts and no life goes on in their absence. Injecting pure distilled water into the blood would be a very dangerous proceeding, but injection of water containing the same salts as the blood and in the same proportion, is not only safe, but

is often the means of saving life when a large share of the blood has been lost through bleeding.

Mention of bleeding reminds one of the remarkable fact that a cut through the skin does not go on bleeding forever, but stops usually in a few minutes unless the wound is deep. Since the blood is a fluid, why should it cease to flow? The answer is that the blood contains a substance, called *fibrinogen,* which has the curious property of clotting, changing to a stringy solid substance. This fibrinogen, as long as it is in the blood vessels, remains dissolved in the blood; but when it reaches a wound, it changes to the solid form and so plugs up the cut vessels and stops the escape of blood. The cause of this change from the liquid to the solid form is not certainly known, but it appears to result from the joint action of several components of the blood; and it appears, moreover, to belong to the class of changes which are produced by "enzymes." Other such changes will be met when we come to study digestion. Here it is worth noting that the clotting of the blood is due to an enzyme, because this fact explains something important regarding the clotting. The clotting, like other changes due to enzymes, goes on best in the warmth, and is delayed by cold. Curiously enough, there is a

common practice, when the finger has been cut, of plunging it in cold water, as if that were going to stop the blood. It does lessen the flow of blood to the cooled hand, but it delays the important process of clotting. It is much better to leave the hand warm, slowing the flow of blood by keeping quiet, and, if necessary, by compressing the wrist or the arteries above the cut; and, meanwhile, pressing a clean cloth or wad of absorbent cotton against the wound. Heating the cloth would be better than cooling it, for warmth favors the clotting; but the mere presence of the cloth or cotton at the wound helps along the clot, since, for some reason, the presence of a foreign body in contact with the blood hastens the change from the liquid to the solid condition.

In such minor accidents, it should be remembered that the mere loss of a little blood is nothing serious. Except when an artery has been cut and is spurting rapidly, there is little danger from loss of blood. In slowly bleeding cuts, what is more important than to check the blood is to keep dirt out of the wound. Dirt means germs and festering of the wound; cleanliness means rapid healing. If dirt is already in the wound, it should be washed out with warm water (and it would be a good plan also, to apply some

germicide, such as peroxide of hydrogen). Any cloth that is pressed against the wound should be clean—sterile, like the sterilized gauze and cotton that are sold for dressings. A handkerchief or towel that has not been unfolded since ironing is pretty safe; or any cloth after being freshly heated. If nothing clean is at hand, then the cut surface should not usually be touched.

Besides the water and the salts, the foods and wastes, and the fibrinogen, there are yet many other substances dissolved in the blood. What are called the "internal secretions" are fluids secreted by several glands in different parts of the body and poured out by these glands into the blood. Some of these internal secretions are necessary for health and activity, but a full account of them would make rather difficult reading. Poisonous substances are also likely to be present in the blood. The ill feeling in a hard cold is due, no doubt, to poisons circulating in the blood vessels; and the heavy feeling in constipation is due to poisons absorbed from the intestine and passed around in the blood. In more serious diseases, more dangerous poisons are generated and enter into the blood stream; and, along with these poisons or "toxins," there may be present the "antitoxins" generated by the body in its fight

with disease. All these poisons and internal secretions are present in the blood only in very small quantities, but they are none the less important to the body, for weal or for woe.

Besides all these substances that are dissolved in the blood and make part of its fluid, there are a vast number of solid particles floating in it. These are the corpuscles of the blood, and they are principally of two sorts, the red and the white corpuscles. It is the red corpuscles that give the color to the blood. They are so numerous that they make up about a third of the whole mass of the blood. In every cubic millimeter of blood there are about five million of them (or 15,000 times this number in a cubic inch). The white corpuscles are very much fewer than the red.

The red corpuscles are tiny discs, thin at the center and thicker around the edge. They are formed in the red marrow of the bones, and pass from there into the blood. They are cells, similar in a general way to the cells that form the organs, but are imperfect as cells, in that they possess no "nucleus." As the nucleus is essential to the full life of the cells, the red corpuscles are probably short-lived. New ones are continually being formed in the bone-marrow to take the place

of those that have disintegrated. When much blood has been lost through bleeding, the production of new corpuscles goes on apace, until, after a few days or perhaps weeks, they are again present in normal numbers.

The redness of the red corpuscles comes from the presence of a substance called *hemoglobin*—a substance belonging to the general class of proteins, but unusually complex and containing a small proportion of iron. The iron has something to do with the color and also with the use of these corpuscles. The peculiar property of hemoglobin, which gives it its use in the body, is the power of taking up oxygen readily, and of parting with it readily again. What happens is this: the blood, in the course of its circuit through the body, is carried to the lungs, and there comes almost into contact with the air, being separated from it only by thin membranes through which the gases of the air can pass. Here the hemoglobin of the red corpuscles absorbs oxygen from the air. So the blood coming from the lungs is laden with oxygen. Continuing its circuit, the blood passes in due time through the muscles and other organs, and here the red corpuscles give up the oxygen which they absorbed in the lungs. An active muscle cell,

or any active cell, uses up oxygen, and has, as it were, a hunger for more, or an attraction for it; and, though the hemoglobin has sufficient attraction for oxygen to take it from the air in the lungs, it has not enough to hold it against the greater attraction of the tissues. The red corpuscles, with their hemoglobin, are therefore oxygen-carriers, and it is through them that the tissues receive their supply of this essential element.

It was stated that the number of red corpuscles is 5,000,000 per cubic millimeter; but this number varies considerably. It averages 10 per cent less in women, perhaps in relation to their less vigorous muscular activity—for it is the muscles, more than other organs, that require oxygen. Muscular exercise, and "going into training," increases the number of red corpuscles; and the number is greatly increased by going into the high mountains, where the air is thin, and where, therefore, the carrying of oxygen from the lungs to the other organs is a more difficult task. The condition called anemia, or, literally, bloodlessness, is not a lack of the proper quantity of blood, but a deficiency in the number of red corpuscles and of their hemoglobin. The anemic person has a deficiency of oxygen-carriers, and, though he may

be comfortable so long as he is quiet, he suffers from lack of oxygen as soon as he climbs a hill or undertakes any vigorous muscular exercise. Iron is given as medicine for anemia in the effort to supply one of the elements of the deficient hemoglobin.

The white corpuscles of the blood, though so much fewer than the red that there is only one white to a thousand red, are important enough. They differ from the red corpuscles in being true cells with a nucleus, and they even have the power of independent movement, and are much like one-celled animals in the blood. They do not, however, like animals in the full sense, reproduce their kind, but are formed by cells in the marrow of the bones. Their power of movement enables them to escape from the blood vessels, and they accumulate in a festering wound and form part of the pus. They seem to have the power of eating up germs and foreign matter present in the wound, and thus of protecting the body against the spread of infection. In other ways, too, they probably contribute to the fight against disease.

Though the blood comes in very close proximity to the cells of the various organs, it does not come into direct contact with them; but there

is another liquid in actual contact with the cells on one side, and, except for the thin walls of the small blood vessels, in immediate contact with the blood on the other side. This is the fluid known as *lymph.* It is a colorless liquid, and may be observed oozing from scratches of the skin, when these are not deep enough to reach the blood vessels. Lymph contains no red blood corpuscles, but otherwise its composition is nearly the same as that of blood. It contains some of the white corpuscles, which, by their independent power of movement, have made their way out from the blood vessels; and it contains the salts and the food substances of blood, though some of them are less concentrated in lymph than in blood. Lymph contains also the many other ingredients of blood—the internal secretions, the oxygen, the carbon dioxide and other tissue wastes. The lymph is formed partly by the passage of water and dissolved substances out through the walls of the small blood vessels, and partly by the passage of water and dissolved substances out from the cells of the tissues. It, rather than the blood, must be regarded as the direct nutritive fluid of the cells, and as the direct receiver of wastes. Oxygen and food substances pass from the blood to the lymph, and from the

lymph to the cells; while carbon dioxide and other wastes pass from the cells to the lymph, and from this to the blood.

The lymph is partly contained in spaces about the cells, and partly in special vessels. The lymph vessels have delicate walls, and are hard to see and to follow; but they have much the same arrangement as the veins, small ones uniting to form larger ones, and these finally uniting into large trunks, which open into the large veins close to the entrance of the latter into the heart. The flow of lymph in these vessels is towards the heart; and the result is that the lymph is continually being discharged back into the veins and mixed with the blood. The flow of the lymph is much slower than that of the blood. It is helped along by contraction of the muscles, squeezing forward the lymph in and about them; and it is helped also by massage. The rules for massage call always for a squeezing of any part in the direction of venous flow, which is also that of the lymph flow, that is, towards the heart. This squeezing motion, repeated again and again, assists the flow of lymph, and so helps to clean out the wastes of the tissues and attract nutritive substances from the blood. Thus massage is a decided benefit after fatiguing exercise, which

has loaded the tissues with waste; and it is also a benefit immediately after a bruise has been sustained; it prevents the accumulation of lymph in the bruised place, and will often prevent a swelling at the location of the bruise.

When the skin is cut or rubbed off, and the wound is not properly cleansed, so that germs remain in it and cause the formation of pus, it often happens that some of the pus germs find their way into some near-by lymph space, where they accumulate and form an abscess. Even so slight a wound as is produced by the shoe rubbing off a bit of skin may thus, if neglected, be the origin of serious trouble.

Study of the blood and lymph raises many questions that can be answered only by passing on to other parts of our subject. The blood carries foods; we should like to know how these foods get into the blood, and thus we are led to the study of digestion. The blood carries wastes; we should like to know how these wastes are produced and how they are removed from the blood—and thus we are led to the study of excretion. But, first of all, we would understand the mechanism by which the blood itself is kept in motion, and thus we are led to our next topic, the study of the circulation.

CHAPTER III

THE CIRCULATION

The blood is said to circulate because it leaves the heart and comes back again to the heart. It leaves by the arteries, and comes back by the veins. The heart pumps the blood first into a large artery, and this divides into branches, and these in turn into smallcr branches, till there is a little artery running to every corner of the body—to every organ and every part of every organ. Corresponding to each of these small arteries is a small vein, and, going towards the heart, you will find these veins uniting into larger ones, and these into still larger ones, till one great vein finally returns the blood to the heart. But this does not explain how the blood gets from the small arteries over into the small veins; the way in which this is accomplished could not be observed till the invention of the microscope; for the connection is by microscopic pipes or vessels, called the *capillaries*. Though small, they are very numerous; so that the circulation may be described by saying that the blood passes

from the heart into one large artery, thence into many small arteries, and thence through millions of capillaries into the veins, and so back to the heart. The capillaries are the most important part of the whole system; for it is in these little, thin-walled tubes that the blood comes into close contact with the living cells. From the capillaries it is that the foods pass out of the blood to the cells; and it is by way of the capillaries that the wastes of the cells reach the blood. The arteries exist for the purpose of carrying blood to the capillaries, and the veins for taking the blood from the capillaries back to the heart.

Since the heart does nothing to the blood except to keep it moving, the only good of the blood returning to the heart is to get another shove which may carry it to some other organ than the one it has just left. There would be no benefit in the same blood that has just left an organ going back directly to the same organ; but the blood from all sources is mixed as it passes through the heart, and what has just come from the intestines, bringing food, will go, on the next trip, partly to the muscles that require food, while that just in from a muscle and bringing waste will go, in part, to the kidneys and lose this waste. There is no way of steering the

blood from a muscle entirely to the kidney, nor the blood from the intestines or liver entirely to a muscle that needs food; the only thing is to mix the blood well and to keep it moving at a good rate, so that in a short time what has come from any one part can reach any other part.

There are two exceptions to the plan of the circulation just sketched—two cases in which the arrangement of the vessels is such as to steer the blood from one organ directly to another. The first exception occurs in the vein that collects the blood from the capillaries of the intestines; instead of making directly for the heart, this vein runs to the liver and there branches into small veins and finally into capillaries; and only after passing through these liver capillaries does the blood from the intestines get back to the heart, and into the general circulation. The effect of this arrangement is to give the liver first chance at the foods collected from the intestine during the digestion of a meal. The liver takes up the surplus sugar, etc., just absorbed into the blood from the intestine, and stores it up till the supply in the blood begins to run short.

The other exception is even more important. The lungs are treated differently from any other

organ in the body; they have a circulation all to themselves, and receive not a part of the blood, but all the blood. All the blood returning from the body to the heart is pumped directly to the lungs through a special set of arteries, which split up in the lungs into smaller arteries and capillaries. These capillaries are spread out into a broad, thin surface in close contact with the air of the lungs. The lung capillaries lead in turn to veins, and these veins unite into larger ones which carry the blood from the lungs back to the heart, which pumps it out again to the body. The lungs receive this immense quantity of blood not because they need the blood, but because the blood needs contact with the air in the lungs—needs to take up oxygen and get rid of carbon dioxide, one of the principal wastes of the body. Especially in muscular activity is it imperative to get rid of this waste quickly and to get oxygen rapidly, for muscular activity uses up oxygen and forms carbon dioxide.

If the heart were a single pump, it could not thus separate the blood for the lungs from that for the body generally. It is a double pump: the left side of the heart is separate from the right, and pumps the blood over the body, while the right side pumps it to the lungs. The blood

makes a double circuit. Starting from the left side of the heart it passes by the arteries, capillaries and veins of the body around to the right side of the heart, and from there it passes by another set of arteries, capillaries and veins through the lungs and back to the left side of the heart. In reality the two circuits form only one complete circuit, for it is only after going through both that any drop of blood can get back to the exact point from which it started. A drop of blood, now in a muscle, must go through the lungs before it can get back to the muscle; and a drop now in the lungs must go through some other organ before it can get back to the lungs.

The heart is really two pumps or syringes, but these are united into one compact organ. Looked at from the outside, the heart is a conical mass of muscle, with the point of the cone downwards and slightly to the left. Examined internally, this muscle is found to be hollow; and in fact to have two holes through it, one on the right side and one on the left. The muscle is thicker and stronger on the left side, because the work done in pumping the blood about the body is greater than that of pumping it through the lungs. Each half of the heart has a set of valves to prevent backflow; and each

has, besides the "ventricle" or main pump, an "auricle," which is a sort of auxiliary pump acting to fill the chamber of the main pump. The blood flows gradually from the veins into the auricle, and this pumps it into the ventricle, which then pumps it into the arteries. The auricle beats first, and immediately after it the ventricle; and, the two sides of the heart beat together and keep even time, being in fact a single continuous mass of muscle. The action of the heart on the blood is like that of a syringe; it squeezes the blood, while its valves allow the blood to escape only in the forward direction, *i.e.*, into the arteries and not back into the veins. Thus, at every heart-beat, blood is forced from the ventricle into the first large artery. It enters the artery with a jump and a jar which can be felt, as the pulse, through all the smaller connecting arteries. The blood forced from the heart stretches the elastic wall of the artery. The artery is stretched to admit the rush of blood, and then, in the interval between one heart beat and the next, the elastic force of the distended artery squeezes the blood along through the smaller arteries and capillaries; so that the blood does not flow merely in sudden spurts, but all the time, though with pulsations. The pulsa-

tions become less abrupt in the smaller arteries, and in the capillaries and veins the pulse is usually lost and the flow is smooth. The resistance to the flow of the blood is greater in the small arteries than in the large, and very great in the microscopic capillaries. It is the resistance of the capillaries, principally, that must be overcome by the force of the heart beat. The heart muscle supplies the force; the elastic walls of the large arteries temper and equalize the force; till, finally, the blood is squeezed through the capillaries with a slow steady flow.

It is while slowly moving through the capillaries that the work of the blood, as was said before, is accomplished. In the capillaries all over the body, the blood gives up some of its oxygen and takes up carbon dioxide—as well as giving up food substances and taking in other wastes, and in this process it changes from "arterial" to "venous" blood. The hemoglobin of the red corpuscles darkens on giving up its oxygen, and venous blood is thus darker than arterial. Venous blood also contains more carbon dioxide than arterial. This venous blood, returning to the heart (to the right side of the heart) is now pumped through the lungs, and in the lung capillaries it loses carbon dioxide

and takes up oxygen, so becoming arterial again.

The movement of the blood in the vessels is more rapid than one would think. It starts along the large arteries at about the rate of a foot a second, but goes more and more slowly in passing from the large arteries into the many small ones, while in the very numerous capillaries it barely crawls—about a hundredth of an inch a second. But as the capillaries are very short, it spends only a second or so in traversing them. Its flow towards the heart in the small veins is slow, but becomes faster and faster in the larger veins. The whole time of a complete circuit is 20 or 25 seconds, but this includes the circuit through the lungs as well as that through the rest of the body. The time occupied in going from the heart to the lungs and back is only about 5 seconds, and that occupied in the body circuit is about 20 seconds, varying according to the distance of the organ traversed from the heart. The oxygen carriers of the blood thus carry over two loads a minute.

When, however, the muscles are acting vigorously, this speed of circulation would not be sufficient, because of the large amount of oxygen needed and the large amount of carbon dioxide to be gotten rid of. During muscular activity

the circulation is hastened. There are two ways in which this is brought about. First, as every one has observed, the heart beats rapidly during muscular exercise; it beats fast and it beats hard, and so it drives the blood more rapidly into the arteries, and makes it circulate in less time. At the same time, breathing is hastened, to bring more oxygen into the lungs and to remove the carbon dioxide more rapidly. Whenever the breathing is more rapid, the heart beat will also be observed to be rapid—and both for the same purpose, to accelerate the delivery of oxygen to the active organs and to hasten the removal of their carbon dioxide.

The second factor in hastening the flow of blood during exercise is an enlargement of small arteries, and a lessened resistance so brought about to the flow of blood. The walls of the arteries are not only elastic, as was said before, but they contain numerous muscle fibers running around the artery like rings. When these muscle fibers contract, they narrow or constrict the artery; when they relax, they allow the artery to dilate. Ordinarily, the muscle fibers of the arteries are in a moderate degree of contraction, keeping the arteries to a medium bore; under certain circumstances they contract, as, for example, the

arteries of the skin are constricted by cold, and the skin grows pale from absence of blood. Under other circumstances, the muscular walls of the arteries relax and allow the arteries to dilate, as is seen, for example, when the skin flushes in hot weather or when some emotion arouses a blush. When a muscle begins to act, its arteries immediately dilate, allowing the blood to flow more rapidly through it; and when many large muscles are put in action, as in running, a large share of all the arteries of the body dilate, and the speed of the circulation must be considerably increased.

After exercise, the beat of the heart gradually slows down to its usual rate, and the dilated arteries gradually regain their medium bore. This is economy; the heart beats only fast and hard enough to supply the needs of the organs for oxygen and removal of carbon dioxide—which are, usually, their more pressing needs. A moderate flow through partially constricted arteries has this advantage over a more rapid flow through wide-open arteries, namely, that the blood in the arteries is thus maintained at a good head of pressure, and so is ready, at any moment, to flow rapidly through any muscle or gland that starts to be vigorously active. The

normal resting condition of the circulation is a condition of readiness; any sudden demand for more blood in any organ can be promptly met.

The readiness of the circulatory system for sudden demands is partly due to a factor which has not been mentioned. The largest veins of the body are those that collect the blood from the legs and abdomen. These veins, in a resting condition of the body, are rather lax and dilated, and hold a large quantity of blood as if in storage. Not that this stored blood does not move; there is no really stagnant blood in this reservoir, but there is a broad, deep stream running slowly towards the heart. But the walls of these veins are muscular, and any sudden demand for blood in any quarter of the body acts reflexly to constrict these veins. They promptly squeeze their blood towards the heart; it goes to the lungs and comes back to the heart and almost instantly a large supply of oxygenated blood is supplied to the organ requiring it. Such a sudden demand for blood occurs, for example, when one rises from a lying to a sitting posture, or from sitting to standing. These changes in position are attended by a sudden increase in the rate of the heart beat (as can be told by counting the pulse), and they are accompanied also by

a constriction of the abdominal veins. Now it may happen that a person is "out of condition" for muscular work. He is just recovering from an illness in bed; if he should then rise suddenly from his bed to a standing position, his abdominal blood reservoir might not respond promptly; and though his heart might beat wildly in the effort to supply blood as fast as needed, the organs might not get it quickly enough, and the brain, which demands a good circulation, might be, for the moment, insufficiently supplied. The result of this series of events is likely to be a fainting spell.

If a person finds that he cannot suddenly rise from lying to standing without a tendency to faintness, and without wild beating of the heart, it is a sign that he is "out of condition," and probably needs a course of training, beginning with light exercise and gradually increasing to a moderate degree of muscular effort.

The observant reader has probably felt a query growing within him during the last few paragraphs. He is curious to know what makes the abdominal veins constrict at the right times; and what makes the small arteries dilate just when there chances to be need of more rapid circulation in their neighborhood; and what

causes the heart to hasten its beat when the muscles demand more blood; and what hastens the breathing movements at the right times. These various organs, located in different places, could scarcely work together in such beautiful harmony unless there were some central control exerted over them. Control is, in fact, exerted by means of the nerves, and the center which brings everything into harmonious action is located in the nerve centers—in the spinal cord and the lower part of the brain, called the medulla. In the medulla is a "center" which governs the speed of the heart beat, a center which governs the muscles of the arteries and veins, and a center which governs the speed of breathing. The heart has two nerves, an accelerator and an inhibitory. Through the first, the center hastens the heart beat, and through the second it slackens it. The muscular walls of the arteries have two sets of nerves, constrictor and dilator; through the first the center in the medulla causes the walls to contract and narrow the arteries; and through the second the center brings about the opposite result. When we say that the centers do these things, we do not imply that the centers act arbitrarily or all of themselves. They act, the rather, as they are themselves acted on by

incoming or sensory nerves from any and all portions of the body. The manner of their working is, for example, as follows: A cold object placed against the skin arouses the sensory nerves starting from this part of the skin, and these sensory nerves influence the center in the medulla so that it, in turn, acts through the constrictor nerves to check the flow of blood through the skin. This is an example of reflex action; and all of the examples given above of control of the circulation in accordance with the needs of the body or of any organ are probably reflexes.

Since mental life is so large and important a part of the total life of a human being, it is not surprising that the circulatory organs should be affected, not only by the needs of the muscles, etc., but also by thoughts and emotions. A sudden, surprising thought may momentarily stop the heartbeat and then set it to beating wildly, embarrassment may cause blushing, and fear paling or even fainting. These mental influences are to be regarded as exerted by the brain on the circulatory centers in the medulla, and through them on the heart and arteries and abdominal veins.

Though the heart is obedient to the nerve

centers, it is, fundamentally, its own master. It does not require the influences of the nerves to make it act, but will continue to beat, even if its nerves are injured or severed, and even, for a time, if it is cut out of the body, provided it is kept supplied with warm blood. It is what is called an automatic organ, not dependent on stimuli coming from without; but stimuli reaching it from without through its nerves cause it to increase or decrease its action.

Like any other muscle, the heart grows or shrinks according to the amount of work that is thrown upon it. When a man enters on a course of vigorous muscular activity—as when, for example, he goes into training for some athletic game—the heart may be at first severely taxed; but, if it is not urged too fast, it grows till it can meet the increased demands made on it. One should not expect it to become strong instantly; it must be given time to grow, like any other muscle. When a life of vigorous muscular exercise is abandoned for a life of comparative bodily inactivity, the heart muscle gradually shrinks towards its former strength. But there are limits to the power of any individual's heart to accommodate itself to such changes of life. When the demands on the heart are in-

creased, not only must its muscle grow, but the hollow of the heart must enlarge to receive the larger volume of blood now required; and such enlargement may be too much for the size of the heart valves, so that the heart becomes a leaky and inefficient pump. Also, in regaining its former strength on going out of severe training, the hollow of the heart may not shrink; so that the heart may be left a large flabby organ, quite inferior to the smaller organ that it formerly was. Two practical conclusions follow: The more severe athletic sports should not be entered upon without a preliminary examination of the heart by a physician; and steady, moderate exercise, persisted in throughout life, is better than violent forms of exercise in youth, followed by a sedentary life with no regular exercise.

CHAPTER IV

BREATHING

The most important fact about breathing has been already mentioned under the blood and circulation. The use of breathing is to "aerate" the blood, which means to pass oxygen into it and take carbon dioxide from it. The oxygen is carried by the hemoglobin of the red blood corpuscles, and given up by them, in the capillaries, to the several organs of the body. The carbon dioxide enters the blood in the capillaries, from the several organs, and is carried in the blood to the heart and then to the lungs. The lungs do not use the oxygen of the air, nor does the blood use it. The tissues in general use it, while the blood simply carries it to the tissues, and the lungs provide a means of bringing the blood into close contact with the air.

The lungs are thin elastic bags, but internal examination shows them to be very much branched bags. They are branched much like a tree. The windpipe is the trunk, and the "bronchi" are the first large branches; these ramify

into the bronchioles, and these finally end in millions of little expansions, vaguely resembling the leaves of the tree. If the trunk and branches of a tree were hollow tubes, and the leaves were hollow bulbs, the comparison would be fairly exact. The thin walls of the little expansions or end-chambers are crowded with the capillaries of the pulmonary circulation, and through these the blood passes, in close proximity to the air in the little chambers. There it is that the blood is aerated.

Though the air chambers of the lungs are very minute, they are so numerous that, taken together, their walls have an area equal at least to that of a surface ten yards square. This large surface is constantly covered with a very thin layer of blood (in the capillaries), and thus the conditions are highly favorable for thorough aeration of the blood.

The air in the lungs needs to be continually renewed, otherwise contact with the blood would exhaust its oxygen and saturate it with carbon dioxide. The air is renewed by the movements of breathing. Breathing in, or inspiration, brings in a quantity of fresh air to mix with that already in the lungs; and breathing out, or expiration, removes a part of the air in the lungs.

Expiration does not completely empty the lungs —far from that; force expiration as hard as you can and you still leave a considerable volume of air in the lungs. But the mixture of the air taken in with that already in the lungs renews the air sufficiently. Quiet breathing, which goes on when the body is at rest, renews the air but slowly; but at such times the blood needs but little oxygen and has but little carbon dioxide to give up. Muscular exercise is attended by fuller inspirations and more complete expirations, and thus the air is rapidly renewed.

The lungs are soft and elastic; they are enclosed in a firm box, the chest, the size of which is changed by the movements of breathing. Inspiration enlarges the cavity of the chest and expiration diminishes it. The inward movement of the air results from the pressure of the air outside, and the movement outwards results from squeezing the air in the lungs; in short, as far as the motion of air is concerned, breathing differs not at all from the use of an ordinary bellows.

There are two ways in which the cavity of the chest can be enlarged: One by raising the ribs, and the other by depressing the diaphragm. This last organ is a sheet of muscle and tendon,

forming the floor of the chest and separating it from the abdomen. This floor of the chest is not flat, but dome-shaped, higher in the middle than at the edges, where it is attached to the bony walls of the chest. When the muscle fibers of the diaphragm contract, they flatten the dome, and so increase the space within the chest. In order to flatten out in this way, the diaphragm must press downward the liver and stomach lying just beneath it; these and the rest of the abdominal organs, such as the intestines, are moved by the diaphragm, and this motion can be seen at the front of the abdomen, which moves out in inspiration and back in expiration. Diaphragmatic breathing is therefore often called abdominal breathing. In distinction from this, we have rib or costal breathing. The ribs are lifted by muscles lying between them, and since each rib, attached behind to the spine, extends forward and downward, raising the ribs also brings the front of them forward, and thus enlarges the chest. In energetic breathing, both movements, that of the diaphragm and that of the ribs, occur together; but quiet breathing may go on by use of the diaphragm alone. Diaphragmatic or abdominal breathing is easier, more economical, than costal breathing; but it is im-

peded by a tight corset or belt, and such *luxuries* must be paid for by extra muscular work in breathing. What is more serious is that the abdominal organs, at all times rather liable to sluggishness, are normally stimulated by the churning motion of abdominal breathing; failing which, the result is apt to be constipation, the cause of much trouble, as those who indulge in tight abdominal clothing can abundantly testify.

The movements of breathing, like those of the circulation, are controlled by nerve centers in the medulla. The medulla is affected through sensory nerves from all parts of the body, so that what occurs anywhere is likely to change the rate and depth of breathing. It seems also as if the quality of the blood at any moment influenced the breathing center, in such a way that blood of venous character—deficient in oxygen and surcharged with carbon dioxide—circulating through the medulla, makes it more excitable, and so hastens the breathing. This is an explanation of the manner in which the need for more oxygen, or for the more perfect removal of carbon dioxide, operates to cause faster and deeper breathing. Unlike the heart, the diaphragm and the other muscles of breathing do not per-

form their rhythmical movement of themselves, but only as aroused, through their nerves, by the breathing center in the medulla. Destroying this center—as in breaking the neck, in hanging and certain other forms of capital punishment—instantly and permanently stops the movements of breathing. This soon produces death, for carbon dioxide, accumulating in the no longer aerated blood, saturates all the organs and poisons them. The heart ceases to beat; the brain succumbs even more quickly; and one by one the organs become poisoned with the products of the body's own action.

Carbon dioxide is then a poison, and it is the poison that usually kills the tissues. But it is only poisonous when present in excess. Some of it is always present in the blood and in all the tissues, and indeed the presence of a certain amount is as necessary for life as the presence of an excessive amount is dangerous. But it is only in unusual circumstances that one needs to worry about carbon dioxide. In a mine, or in a building on fire, this gas, along with the lack of oxygen, sometimes causes death. If many persons, or if even one person, were hermetically sealed up in a room, the oxygen there would in time be exhausted and the accumulation

of carbon dioxide would be dangerous; but even a tightly shut room, as we ordinarily speak of such things, is far from hermetically sealed. It is ventilated to some extent by means of cracks. Even without any definite system of ventilation, it is seldom that the dearth of oxygen or excess of carbon dioxide are bad enough to endanger health. Yet there may be a sense of oppression in a room where many persons have been breathing, and perhaps lamps burning as well; but it has been found that merely setting this confined air in motion by an electric fan does away with most of the feeling of oppression. Now since this movement of the air does not purify it in the least, but simply enables it to cool the overheated skin, it seems to follow that the feeling of oppression in confined rooms is due to the heat and moisture and not to carbon dioxide. However, though we must admit that ventilation is often overdone, and though carbon dioxide in the air of inhabited rooms cannot be the danger to health that it has sometimes been supposed to be, nevertheless good ventilation is certainly desirable—if for no other reason, because of the germs of colds, influenza and even of tuberculosis and other serious diseases which may accumulate when a crowd of people

are breathing a limited quantity of air. Good clean air from out-of-doors, properly warmed, is certainly much to be preferred to the heavy atmosphere of ill-ventilated rooms.

Fresh air has a value that is not fully explained by the facts of respiration. Country air, mountain air, the air of the pine woods or of the open sea—exercise in the open, camping in the woods, sleeping in out-of-door porches—many can testify to the value of these things, but nobody is ready with an explanation. The air of the city streets, or of a well-ventilated room, is scarcely to be distinguished from pure country air in terms of oxygen or carbon dioxide. If I could bring home from my vacation a supply of country air, or pipe it directly into my house, I should probably be disappointed in the results,

"For I did not bring home the river and sky."

We need to take account not only of the air but of the surroundings with their stimulating or depressing influence on the whole man.

CHAPTER V

FOOD

Eating is a clear example of an instinct implanted by nature and followed, in general, blindly but with good results. The need for food is not understood by the animal or infant, nor, indeed, has it been thoroughly understood even by adult men till the recent studies of science made the matter plain. The most ready answer to the question, why we eat, would be, because we are hungry. For practical purposes this is rather a good answer, since hunger usually means that the body needs food. Hunger is the expression of the nutritive instinct. Like other instincts, it is not infallible, for sometimes it is absent when food is needed, and sometimes it persists after the real needs of the body have been met. In fact, a large share of bodily ills result from bad feeding, and here, as much as anywhere, scientific study may be expected to be of advantage as an aid to nature.

In order to consider food from the scientific point of view, we must go deeper than hunger

and ask what use the body makes of food, once it is eaten and digested. We know that substances derived from the food are absorbed out of the stomach and intestines into the blood, and carried by the blood to all the organs for their use. Here the food is put to use in a variety of ways.

One use is clearly seen in case of the child. Since he must grow, he must add to his body materials taken in from outside. Every pound that he gains in weight means the retention in his body of a pound of food. But since the child may take a quart of milk every day for a year, or over seven hundred pounds in all, while gaining only ten or twenty pounds in weight, it is clear either that the child eats out of all proportion to his needs, or else that he has other uses for food. And what is the use of food to an adult who has reached his full growth, and who, perhaps, remains for ten or twenty years of the same weight? The great bulk of our food, it would seem, must have some temporary use to the body; we must somehow derive good from it and then get rid of it. What we derive from it, for the most part, is *energy*.

Life consists in activity, in movement. The body, or some of its organs such as the heart,

are in perpetual motion. Now perpetual motion, as we all know, is impossible—that is to say, it is impossible when understood in the sense of those who try to invent a perpetual motion machine; for what they are striving for is some contrivance that, once set in motion, will constantly keep itself going with no external aid, while still overcoming the necessary friction, or otherwise doing a certain amount of work on objects external to itself. The work done acts as a steady drain on the motion of the machine; it slows down this motion and eventually brings the machine to a halt. In order to produce continued motion against resistance, there must be a continued supply of energy, to supply what is lost from the machine in doing work. The much-desired but impossible "perpetual motion machine" would be one which constantly gave off energy in doing work and yet never needed any fresh supply of energy. But if there is a continued supply of energy, any machine will keep on moving until it gets out of repair. A steam engine will work as long as steam is supplied—as long as coal is burned in its furnace—provided of course that it does not wear out or get out of repair at any point.

The human body is run on the same general

principle as the steam engine. Its wonderful perpetual motion is due to a continued supply of fuel, as well as to a remarkable power of keeping itself in repair. It creates no new energy, but only utilizes energy supplied to it. It makes no motion without consuming a certain amount of energy. Every breath or heart beat or movement of the hand or foot or tongue requires the burning of a corresponding amount of fuel.

Food is the body's fuel. It consists of combustible material, that is to say, of material that can chemically combine with oxygen, the necessary oxygen being taken in through the lungs. The combustible material of the food unites within the body with oxygen derived from the air, and this combustion or burning of the food is the body's fire, equivalent to the fire which supplies the steam engine. The body's fire is, indeed, remarkable in being a very slow fire; the food burns at a comparatively low temperature; but, none the less, it burns, and in burning gives out heat and other forms of active energy. The warmth of the body represents part of this energy, and muscular movement represents another part. By no magical process does the body create either its warmth or its motion out

of nothing, but both are transformations of the energy stored in food.

To look at food, one would not suspect it to be a store of energy. Lifeless, inert, cooked it may be, it seems anything but a source of movement. Its energy is indeed latent or "hiding," potential as distinguished from active or kinetic. Its potential energy is simply its capacity to unite with oxygen. The potential energy of food was stored away in it by the plants that first formed the food—for all food, whether vegetable or animal when eaten, comes originally from plants. The plants have made it out of inorganic materials, the carbon dioxide from the air, water and nitrates from the ground; the plants have taken in these oxidized substances and deprived them of part of their oxygen, so making substances which, being relatively free of oxygen, can combine with it again. To tear out oxygen from an oxidized compound is a process requiring energy; and the plant no more than the animal possesses any magic power to do such work without being itself supplied with energy from without. It derives its energy from the sunlight; and thus, when you trace things back, you find the sun to be the source of the potential energy of food and

thus of all the activities of animals and men.

Fuel, then, is a prime need of the body, and for this the great bulk of food is eaten. What we want of it is not its substance, but the energy stored in it. This energy we extract by oxidizing it, and then throw off the substance again as waste. Only a small part of what is taken into the body has the use of building material; the greatest part is fuel; for the body is a busy place, much more like a factory than like a church tower.

Food has yet another use besides those mentioned. The body needs a lubricant, and this it finds in a substance which must be reckoned as one of the most important of all foods, namely, water. A dry joint between two bones would be neither comfortable nor economical of muscular effort; but every joint is enclosed in a bag or capsule of membrane, filled with a liquid which is mostly water; and, by aid of this lubricant, the smooth ends of the bones turn with the greatest ease one on another. The heart is enclosed in a similar bag of liquid; the lungs likewise; and everywhere throughout the body where one mass must move over another, friction is reduced by liquid filling all the spaces.

In case of the circulation of the blood, again,

the use of water as a lubricant is readily seen, for bits of nutriment could not be carried rapidly about the body unless they were dissolved or suspended in some fluid medium. The food cannot even get actually into the body, cannot be absorbed from the stomach and intestines into the body proper, until it has first been dissolved. And the waste matter that is continually being formed by the activities of the several organs could not be carried to the organs of elimination unless it were dissolved. Water is indispensable for circulation.

But within the tissues themselves, water is no less a prime necessity. The life and activity of the organs consist in minute motions within them, such motions as are only possible in a fluid or semifluid medium. Every living cell is semifluid inside, and its life consists of minute motions within the fluid. The inner machinery of life is of a much more subtle character than the visible motion of the masses of the body; the machinery is of a chemical nature, and the ultimate activities of life are such as can go on only in solutions. Dry out the water of a tissue and its life ceases. Water is therefore a needed lubricant to the inner and minute mechanism as well as to the large machinery of the body.

Besides this, water performs another sort of service, for the evaporation of perspiration from the skin is one way in which the temperature of the body is regulated and prevented from going too high.

It is not surprising, in view of all these facts, to learn that water is one of the largest constituents of the body and of the food. It is, in fact, the largest constituent, amounting to nearly 60 per cent of the weight of the body. The active organs, muscles, liver, brain, etc., are about 75 per cent water, and the blood nearly 80 per cent.

The proportion of water in the food is correspondingly high, for nearly every food consists very largely of water. It is probably possible to take in sufficient water in milk, fruits, vegetables and other juicy foods, without ever drinking any water clear; but it is usually desirable to take it as a drink, in addition to what is contained in other foods.

Yet another use of food is less easy to understand than the needs for building material, fuel and lubricants. Certain inorganic or mineral substances are as essential to the body's welfare as are those vegetable and animal compounds that form the great bulk of the food. The

mineral substances belong to the class of compounds called salts, and one of them is indeed common table salt, or sodium chloride. Certain salts of the metals potassium and calcium are also necessary. Much of the calcium salt has, indeed, an obvious use; for the rigidity of the bones is largely due to the large quantities of the salts of lime (or calcium) contained in them. Calcium must therefore be eaten, especially by the growing child; much of it is contained in milk, and in many vegetables. Occasionally the diet of a child, composed too largely of meat, is so deficient in calcium that his bones do not calcify properly; and the child gets into the condition known as "rickets."

In a few other ways the salts play an obviously important part. The gastric juice, an agent of digestion, is partly composed of hydrochloric acid, and the chlorine of the acid is derived from the sodium chloride of food. Sodium plays an important part in the blood, from its power to unite with the carbon dioxide formed in the oxidation of food, and to set free this carbon dioxide again in the lungs.

But aside from these special uses, there is a more fundamental and less obvious use of the salts—a use not thoroughly understood, but

made certain by such facts as the following. Unless the blood contains the proper salts of sodium, potassium and calcium, the heart refuses to beat, and the muscles and nerves soon lose their activity. Fuel and oxygen may be abundantly present, and the structure of the heart or muscle may apparently be the same as ever, but all power is lost. Every living cell contains these salts and cannot live without them. In some way, their particular chemical properties play an essential part in the intracellular motions which constitute life.

Besides the metallic salts just mentioned, there is another metal which must be present in some form in the food. Iron, as was observed in speaking of the blood, is an essential element in the composition of hemoglobin, the red coloring matter of the blood, and is necessary in the oxygen-carrying power of the red corpuscles. Iron must therefore enter into the composition of the food.

Though water and the salts are certainly known to play an essential part in the inner life of the cells, it is by no means easy to figure out precisely what that part is; and the same can be said regarding another intimate and recondite use of the cells for food. In order to be

alive the cells must maintain a certain structure, and this structure requires the presence of delicate membranes or surfaces within and around the cell. If the cell had no surface, definitely separating it from the lymph in which it is bathed, it would simply melt away into the lymph and lose its individual existence and all of its peculiar cellular activities. The external surface of a cell is more than a mere geometrical surface, for it separates the cell from its surroundings; and this means that it acts as a barrier to free passing of water and dissolved substances. If diffusion were perfectly free from the outside to the inside of the cell, and vice versa, the cell would simply dissolve in the lymph and be lost. The outside boundary of a cell has many interesting physical and chemical properties, and these are essential to its life. Moreover, it is likely that there are similar boundaries or surfaces within the cell, and that these have an important part in the cellular activities. The "nucleus" of the cell should also be thought of in this connection. This nucleus appears as a little core of greater density than the great mass of the cell—which latter is called the "cytoplasm"; and the chemical composition of the nucleus is peculiar in that it contains phosphorus.

The nucleus is essential, for any portion of the cytoplasm cut off from the nucleus dies, whereas portions containing the nucleus or a part of the nucleus may live and regenerate the missing parts of the cell. The nucleus is necessary to the reproductive power of the cell, and probably to its other vital activities. Not only the nucleus, but also, probably, the surfaces within and around the cell, have a peculiar chemical composition. These surfaces seem to be composed in part of fatlike substances, or "lipoids," such as lecithin and cholesterin. These chemical details are mentioned to show that food is needed not only for fuel and for building up the cytoplasm or general body of the cells, but also for furnishing suitable materials for the minute inner structure of the cells. Foods containing phosphorus seem to be especially needed for this latter purpose.

Having now considered the uses of foods, we will next examine foods as they are eaten, and see how they meet the needs of the body. Aside from water and salts, which have already been sufficiently discussed, all foods, though so varied in appearance and taste, are found on chemical analysis to consist of three classes of substances,

called protein, carbohydrate and fat. Almost every food, as eaten, is a mixture of all of these, along with salts and water. Some foods contain more of one kind, and some more of another; as, for instance, meat consists principally of protein (and water), bread contains more carbohydrate than anything else, and butter is almost pure fat. White of egg is another good example of protein, and olive oil of fat, while sugar and starch are pure carbohydrates.

All of these substances are what the chemist calls organic compounds; they all contain the elements carbon, hydrogen and oxygen.

Protein is a much more complex compound than the other two sorts, and in fact is the most complex sort of compound known to chemists. Besides carbon, hydrogen and oxygen, it contains the element nitrogen and a little sulphur; and some proteins contain also phosphorus or iron. Since proteins are the only foods that contain nitrogen, they are sometimes spoken of as nitrogenous foods, in distinction from the non-nitrogenous foods, fat and carbohydrate.

If any reader is curious to know more exactly the composition of protein, and the structure of the immense protein molecule, he may be informed that the molecule is composed of a

number of sub-molecules which are alike in possessing the radicles NH_2 and COOH, and are therefore "amino-acids." There are many slightly different amino-acids, and many different proteins result from their varied combination. The protein molecule seems to be a rather loose union of these smaller molecules, and to be broken up and reformed rather freely in the processes of the body. The analysis of protein has been one of the most difficult tasks of the chemist, and much yet remains to be done before it is thoroughly accomplished.

Carbohydrates are chemically much simpler than proteins, containing no nitrogen nor sulphur, but only the three elements, carbon, hydrogen and oxygen. The simplest of the carbohydrates are the sugars; next to these stand the starches, and the most complex is cellulose, the fibrous material of plants, which is hardly to be reckoned as human food, being too tough for our digestive apparatus. Of the sugars there are several kinds, some more complex than others. Cane sugar, the most familiar and the sweetest, made from beets as well as from cane, is less simple than glucose. This last, along with a very few others, is the simplest form of carbohydrate. It has rather a bad repute with

the public, because it is known to be used as an adulterant of cane sugar. It is, in fact, produced very cheaply from Indian corn or potatoes, and it is not a perfect substitute for cane sugar because it is not so sweet. It is, however, just as nutritious, and fully as digestible. In fact, while cane sugar requires a little digestion before being ready to enter the blood, glucose, being already the simplest carbohydrate, requires no digestion, but passes unchanged into the blood. Glucose is *the* sugar of the blood and of the body in general. All forms of carbohydrate are reduced, in digestion, to glucose or very similar sugars, and so made ready for the body's use. Starches, being somewhat more complex than cane sugar, require a more extensive process of digestion; but as they are more abundant than sugar in plants, as for instance in potatoes, grains, and peas and beans, they constitute the bulk of our carbohydrate food.

Fats are compounds of the same three elements as carbohydrates—carbon, hydrogen and oxygen—but the proportions are different. The proportion of oxygen is large in carbohydrates, but small in fats. Since they contain little oxygen, the fats can take up much more in being oxidized; and the more they take up,

the greater is the heat or other energy liberated. Therefore fats are a concentrated form of fuel, the most concentrated of all the fuels consumed by the body.

These then are the chief classes of foods; and the next question concerns the manner in which the body uses each sort. It will be recalled that the body has two main uses for food: (1) to build up the substance of the body and repair its waste; (2) to burn as fuel for the supply of heat and other forms of energy.

For building and restoring the living cells of the body, only protein, along with water and salts, and a little of such substances as the lipoids and nucleins, can be used. This is evident from the fact that living cells are built of protein and the other substances just mentioned, whereas carbohydrates and fats, though often present in cells, seem to form no part of the machinery or active structure, but rather to be there simply as fuel. A child might be abundantly fed on fats and carbohydrates, but if he ate no protein, he could not grow, because the nitrogenous building material for the cells would not be at hand. A man might eat heartily three times a day of sugar, starch and fat, but if he ate no protein he would be all the time starving

to death, as surely, though not as rapidly, as if he were eating nothing at all.

Fats and carbohydrates are not building material, but fuel. Fat has indeed a secondary use as padding and weather-proofing; a layer of it beneath the skin helps to retain the body's heat, and cushions of it deeper in the body probably protect delicate organs from jars and jolts; and, besides, a reasonable amount of it contributes to good looks. But it does not form part of the vital structures, as protein does. Carbohydrate is not so much stored as fat, and is purely and simply a fuel; but it seems to be, on the whole, the fuel that the body most prefers.

Since protein, besides its use as a cell-builder, is also a fuel, it can, if taken along with salts and water, support life without the addition of fat or carbohydrate. It is the only one of the three great classes of foods which can support life alone; and under unusual circumstances it is, in fact, adopted as the sole food. Certain tribes of Indians in the Pampas of South America are said to subsist, year in and year out, on lean beef from the herds which they tend, and therefore to live on protein alone. But such a diet is not economical for the body, nor, in most places, for the pocketbook.

Regarding the principles of good eating and the choice of a diet, much remains to be said; but it will be better appreciated if postponed till the digestion of food has been examined; for food must be chosen, not only with regard to its ultimate use, but also with some consideration for the organs that have the task of digesting it and so putting it into such shape that the body can utilize it.

CHAPTER VI

DIGESTION

The mouth is the entrance to a long tube, which passes down through the neck and chest, winds about many times in the belly or abdomen, and finally opens to the exterior again at the anus. The several parts of this digestive tube are called by special names: Next behind the mouth comes the throat, below this is the gullet, which extends straight down through the chest, penetrates the diaphragm and opens into the stomach; this in turn opens into the bowel or intestine, the winding portion of the tube, which fills with its numerous folds a good share of the belly, and would, if stretched out straight, reach a distance of twenty-five feet. The intestine has two parts: the "small intestine," coming next after the stomach, is long and narrow; it leads to the "large intestine."

For most of its length, the digestive tube is narrow, an inch or two in diameter, but the stomach has a diameter of four to five inches, and in some persons much more. It is distens-

ible and collapsible, and is much larger after a heavy meal than before it.

One of the chief uses of the stomach is to serve as a bin. Enough food is heaped into it in half-an-hour to keep the digestive machinery busy for several hours. The stomach dilates to receive all that comes, and then doles it out slowly to the intestine, in which the greater part of digestion is accomplished.

The stomach acts also as a churn. Its muscular walls squeeze and squirt the food to and fro, and gradually mix it up into a mush, which can safely be passed into the tender intestine. Sometimes, after a heavy meal, the churning action of the stomach is not equal to the work put upon it. This is one cause of stomach ache. At such times, kneading the stomach by pressing the hands into the belly over it assists in the churning process, and perhaps stimulates the stomach muscle to greater activity, and so relieves the pain.

Yet another use of the stomach is to destroy the bacteria that are almost always taken in with the food. Many of these bacteria are not specially dangerous, yet among them are some that would cause fermentation and diarrhœa. Most of them are killed by the acid of the gastric juice.

Even some disease germs, such as those of cholera, can be safely swallowed if the stomach is actively secreting its acid. Tubercle and the typhoid bacillus can, however, pass undestroyed through the stomach.

The stomach is not absolutely essential to digestion, as is shown by some cases in which it has been removed by the surgeon, the gullet being then made to open directly into the intestine. Persons on whom this operation has been performed have lived and remained for many years in health, but have been obliged to take their food a little at a time instead of in a few square meals daily. So the stomach, though not an absolute necessity, is a great convenience.

The digestive tube is lined with mucous membrane, a sort of skin, but softer and more tender than the external covering of the body. This membrane has the power, not possessed by the skin, of *absorbing* water and substances dissolved in water. The hand may be held for hours in milk, but no milk will be absorbed by it, and no nourishment will be obtained for the body's need. If the milk had been drunk instead, it would gradually have passed through the mucous membrane and reached the blood, and so have nourished the body. Very little

food, however, passes through the membrane of the mouth, and comparatively little through that of the stomach. Most of it is absorbed by the lining of the intestine. In this part of the digestive tube, the mucous membrane, instead of being smooth, as elsewhere, is a perfect velvet of little projections called *villi,* which are provided with blood and lymph vessels and have special capacity for taking in food. How the food manages to get through from the intestine into the blood vessels, it is not quite easy to see; no holes can be discovered in the membrane even by aid of a microscope. Solid particles, indeed, cannot pass through; it is only water and other liquids, and substances dissolved in them, that can be absorbed.

The organs of digestion are, then, the mouth with its teeth and salivary glands, the stomach with its glands for the production of the gastric juice, the small intestine with its own glands and with its connections with the pancreas and liver, and the large intestine. What happens to the food in its passage along this series of organs may be roughly summarized as follows.

In the mouth, the food is broken up more or less finely, according to the thoroughness with which it is chewed, and is mixed with saliva.

This juice has the power of digesting starch, so that digestion begins even in the mouth. As soon as the morsel is thoroughly broken up and softened—and too often before that—it is carried by the tongue to the back of the mouth and forced back into the throat. The throat, by its muscular walls, immediately closes on the morsel and squeezes it. Since the re-entrance to the mouth is blocked by the tongue, and since the entrances to the nose and windpipe are also closed, the food is forced into the only opening left, namely, into the gullet which stands open to receive it. The impulse given to the morsel by the throat and other assisting muscles is so great that it is ordinarily shot quickly down the gullet to the entrance of the stomach.

The food enters the stomach near the left-hand end of this organ, where the walls are thin and easily distended, and where the action of the gastric juice is not very strong. This end of the stomach, in fact, serves as a receptacle to hold the food, and little digestion goes on there except the further action of the saliva on the starch. The more thoroughly the food has been chewed, the further does the digestion of starch proceed in the stomach. The right-hand part of the stomach differs from the left in being narrower

and less distensible. Its walls are thick and muscular for the churning of the food, and its glands pour out an abundance of acid gastric juice which starts in at once to soften and digest the protein of the food. From the accumulated mass of food at the left end of the stomach a little at a time is squeezed into the right-hand end, and there is vigorously churned back and forth till it is thoroughly mixed with the gastric juice and till its solid lumps are reduced to a pulp. As soon as this condition is reached, the strong ring of muscle closing the right-hand end of the stomach relaxes, and allows some of the mushy contents to escape into the intestine.

On entering the intestine, the food finds itself exposed to the action of new digestive juices, partly secreted by glands in the intestinal wall, and partly poured into the intestines through ducts coming from the pancreas and liver. Until it enters the intestine, the food has been only very incompletely digested; its starchy ingredients have been partially broken up into sugars, its protein has been softened and partially dissolved, and its fats, too, have been slightly affected. But now, at the beginning of the intestine, it is seriously taken in hand. Its protein, its fat, its starch and its sugars, are all subjected

to the action of strong digestive juices. The intestine, while gradually passing it along its slender length, frequently halts a portion of it and squirts this back and forth, mixing it thoroughly with the juices, and bringing what is already fully digested into contact with the villi in the wall, where it is absorbed and leaves the intestine to enter the body proper by way of the blood or the lymph. So thorough is the work of the intestine that, by the time the valve separating the small from the large intestine is reached, fully five-sixths of the food has been absorbed.

The residue passes into the final organ of digestion, the large intestine, and there it usually remains for many hours, being still subjected to the action of the juices which it has brought with it from the small intestine. Most of it is absorbed by the wall of the large intestine, and what remains to be passed out at the anus is not to be thought of as the food which entered by the mouth. The excrement passed from the large intestine contains indigestible portions of the food, and often a small residue of digestible but actually undigested food, but, for the most part, it is composed of the remains of the bile and other juices poured into the intestine. It

is to be regarded, largely, as waste matter passed out from the blood into the liver or large intestine, as other wastes are excreted by way of the kidney. Too long delay in emptying the large intestine hinders the getting rid of these waste products, and also favors the putrefactive action of bacteria in the large intestine, and the absorption of the poisonous products of this putrefaction into the blood and their consequent distribution throughout the body.

Most of the digestive processes are entirely involuntary and beyond the control of the individual. Only the two ends of the digestive tract are under direct control. The intelligent individual can see to it that proper food is taken into the mouth, and that it is sufficiently chewed before being delivered to the action of the stomach and intestines; and he can take care of the regular evacuation of the large intestine. The rest, he must leave to natural processes that are beyond his influence and even beyond his knowledge.

This rough description of the course of events in digestion should be supplemented by something regarding the nature of the changes in the food that are caused by the action of the digestive juices.

The process of digestion is pretty well indicated by the word *solution.* As eaten, food is usually in a solid or semi-solid state, and must be dissolved before it can be absorbed into the blood. Most food is not even soluble in water, and must be chemically changed to make it soluble. Chemical changes are brought about by the action of the digestive juices. Starch, itself insoluble, is changed to the soluble sugar. Fat, itself insoluble, is changed to a soluble soap. Protein is changed from a more complex, insoluble form to a form that is simpler and more soluble, or is even broken up into its constituent amino-acids, which are still more soluble.

But the word *solution* does not tell quite the whole story of digestion. Why should protein ever be broken up into the amino-acids, since some of the simpler forms of protein itself are soluble in water? Cane sugar is soluble, but it is not allowed to remain cane sugar, but is broken up into the simpler sugars, such as glucose. The secret of digestion seems to be something like this: The animal body has its own preferred sorts of protein, carbohydrate and fat, and it does not simply take these in from outside, but manufactures them itself. It does not, and could not, manufacture them from the chemical

elements, nitrogen, carbon, hydrogen and oxygen. This fundamental synthesis can be performed only by plants. But the animal body manufactures its peculiar proteins, etc., out of simpler compounds, such as the amino-acids; and the process of digestion seems to consist in a breaking up of the foods eaten into substances which the body can put together in new combinations to make its own peculiar substances. There are, however, many mysteries connected with this process that science has not yet penetrated.

So much as this is certain: Digestion consists in chemical changes which break up more complex compounds into rather similar but simpler compounds; and the absorption of these simpler compounds into the body proper is accompanied by a building up of more complex compounds different from those that were originally present in the food.

The chemical changes of digestion are produced by the various juices, and principally by *enzymes* contained in them. An enzyme differs from ordinary chemicals in that a small quantity of it can give rise to a large amount of chemical change, and in that the enzyme itself is left behind at the end of the change, as if it had not taken any part in it. Enzymes are sometimes

described as "accelerators," since the changes which they produce would go on without them, but go on much more rapidly in the presence of the enzymes. Each enzyme has a specific action. Most of this class of chemical agents are produced by living cells, and are like living things in being made inactive by cold and destroyed by heat. The enzymes of digestion are produced by the cells of several glands. The salivary glands in the mouth produce an enzyme which acts on starch and breaks it up into sugar. The glands of the stomach produce the enzyme pepsin, which partially breaks up protein. Glands in the intestinal wall produce an enzyme which breaks up cane sugar into glucose. The most important digestive gland, the pancreas, produces several enzymes, one of which breaks up protein, one starch, and one fat. To these enzymes are added the action of the hydrochloric acid which is secreted by the glands of the stomach, and helps in the digestion of protein; and the bile, which assists in the digestion of fat.

The glands and their juices are interesting enough to warrant a fuller study, but for that the reader is referred to the text-books of physiology, since the details are not easily applied to

the regulation of the diet or of health. But there is one fact that can be put to use. A gland works only when it is excited to action by some cause. The glands of the stomach are excited, and the flow of the gastric juice accomplished, either by the action of certain substances introduced into the stomach, or by the action of the stomach nerves, which are themselves aroused to action by the agreeable taste and smell and appearance of food.

Now it is a peculiar fact that pure protein, pure fat, and pure starch, neither have much taste, nor act strongly on the glands of the stomach. If they should be taken in chemical purity, they would not be relished, and would not much excite the flow of the gastric juice. And as the pancreatic secretion is excited by the passage of the gastric juice and partially digested food into the intestine, it too would be deficient. Though the foods eaten were of perfect purity, they would then be but slowly and imperfectly digested, owing to the lack of the juices. Besides the pure food materials there must therefore be *flavoring matters* in the food. Do not jump to the conclusion that abundance of spices, piquant sauces, and other condiments, is necessary to excite the digestive glands. A

certain amount of such relishes may properly be added to the food, but the best flavorings are present naturally in the food; such as salts, sugar, and the flavors of fruits, vegetables, and meat.

One of the most powerful and useful of flavoring matters is the "creatin" present in meat. It is creatin that gives the taste and odor to roast beef, to a steak or chop, or to many soups. Besides its agreeable taste, it has a specially stimulating effect on the glands of the stomach.

When beef is soaked in hot water, the creatin dissolves out, producing "beef tea." If this solution is evaporated, the solid residue is the "extract of beef," which consists mostly of creatin and salts. It is important to observe that the protein, the nutritious part of the meat, being hardened or coagulated by the hot water, does not dissolve out, and is not present in the beef tea or in the extract. These consist of the flavoring matter without the nutritive matter. That the creatin is of no nutritive value to the body is seen by the fact that it passes out, practically unchanged, into the urine. It does not burn and supply energy; and it does not build up the living matter of the body. On account of its stimulating action, it may seem to an invalid or con-

valescent partaking of it to give strength. But for an invalid to try to live on it alone would be a serious mistake. If it is taken along with some real food, as an egg or some toast, it may be of decided value, by promoting digestion; if taken alone it is valueless and even weakening, because it causes useless activity of the glands. For the same reason a healthy person will find either a cup of beef tea or bouillon, or a soup consisting partly of beef extract, an excellent preparative for a meal, but a detriment if taken alone.

The habitual use of strong condiments over-stimulates the digestive glands, and tends to weaken them and so produce dyspepsia. Instead of piling on the condiments and seeking only *intensity* of taste, the better way is to seek enjoyment in the *quality* of the natural flavors.

Still more important than the cultivation of moderate tastes is the preservation of a healthy appetite. A good appetite needs no strong sauce; it is an indication that the glands are charged with their juices and need only a slight stimulus to pour them forth. How to preserve a good appetite? William Penn is credited with this maxim: "Always rise from the table with an appetite, and you shall never sit down without

one." Undoubtedly over-eating is one of the greatest destroyers of appetite. Eating poorly cooked food, or food that is so elaborate as to be hard of digestion, is another. One great promoter of a healthy appetite is exhilarating exercise in the open air; and another is agreeable company and surroundings and mental relaxation during meals.

CHAPTER VII

WASTES AND THEIR REMOVAL

It is only on first thought that the production by the body of wastes harmful to itself seems a strange and unnatural state of affairs. In reality, nature and art supply many analogous cases. A fire produces ashes and carbon dioxide, which must be removed or they would stifle the fire. A machine can scarcely run so smoothly but that it will wear away slowly and need to be cleaned from the accumulation of its own waste. Now the body is a machine, though wonderfully intricate and subtle in its workings; and it is subject to some internal wear and tear. Also, the body uses fuel, and indeed the great bulk of the food is required only for this purpose. The body burns or oxidizes it, extracting its supply of potential energy, as a furnace extracts the potential energy of the coal; and having no further use for it, must get rid of the oxidized remains.

The fuel of the body resembles coal, wood, oil and gas in being essentially composed of the elements carbon and hydrogen; and the oxidized

products of burning this fuel are carbon dioxide and hydrogen monoxide or water. The carbon dioxide is removed by way of the lungs. The water does not need removal as a waste, but it does leave the body by several channels. If the only wastes of the body were these fuel wastes, the means of elimination would be much simpler than is actually the case.

For there are the tissue wastes to be considered. The red corpuscles of the blood are subject to disintegration, and their hemoglobin is changed and eliminated partly by way of the liver and partly through the walls of the intestines. The phosphorus-containing compounds in the nuclei and other parts of all cells undergo gradual decomposition, and the phosphorus is eliminated by way of the kidney and of the intestine. The protein of the cells is subject to slow disintegration, and the nitrogen in it is eliminated by way of the kidney.

From the above it can be seen that the organs of elimination or excretion are the lungs, the kidney, the liver and the intestine. The lungs and intestine have already been described, but the kidney and liver require further attention.

The kidneys are located, one on each side, in the upper and back part of the abdominal region,

a little below the last ribs. They are not large organs, compared with the stomach or lungs or brain; they are as large, let us say, as a medium-sized potato; and they have the shape of a bean, or, in fact, what is familiarly known as the kidney shape. To each runs a large artery and vein, for the kidneys receive a large supply of blood, not for their own advantage but for the purification of the blood. Out of each kidney runs a long slender tube, called the ureter, which conveys the urine, as fast as the kidney forms it, down past several other organs into the bladder, where it accumulates till a convenient time for its removal. The bladder, in turn, has for an outlet a tube called the urethra, which conveys the urine to the exterior. The inner arrangements of the kidney have some resemblance to those of the lung. There are a great number of fine tubes, which unite to form a cavity connecting with the ureter—just as the small chambers of the lungs unite to form the bronchi and windpipe. And just as the chambers of the lungs are surrounded by many blood-capillaries, so the tubules of the kidney are surrounded by capillaries. Through the walls of these capillaries into the cells lining the kidney tubules, from these cells into the tubules, and so on to the

ureter and bladder, are continually passing some of the water of the blood and, dissolved in the water, some of the wastes contained in the blood.

The liver is built on somewhat the same plan as the kidney, but is much larger, being in fact the largest organ in the body. It lies in the uppermost part of the abdomen, just beneath the diaphragm, which separates it from the lungs, while immediately beneath and behind the liver lies the stomach. Like the kidney, it has a large blood supply; in fact, it has a double supply, for besides the artery which brings blood directly to it from the heart, it also receives the vein coming from the intestines. As explained in an earlier chapter on the circulation, the blood returning with freshly absorbed food from the intestines is carried first to the liver, which takes out and stores some of the food. Both the artery from the heart and the vein from the intestines divide into smaller and smaller branches and finally into capillaries. These capillaries unite again to form veins which return the blood to the heart. But in passing through the capillaries, the blood comes in close contact with the liver cells, and is subjected to their action. Another set of fine tubes, the bile-tubes, is interwoven with these cells. The minute bile-tubes come together to

form larger ones, which finally converge into the "gall-bladder," a receptacle lying imbedded in the liver, and analogous in its use to the urinary bladder. It receives the constantly forming *bile,* or excretion of the liver, and stores it until such time as it is discharged. The outlet from the gall-bladder is a tube which empties into the upper part of the intestine. Thus the excretion of the liver is removed by way of the intestine. This excretion, the bile, is in part to be regarded rather as a secretion, since it aids in the digestion of food in the intestine. The liver, in fact, does a more varied work than the kidneys or the lungs; it removes wastes from the blood, discharging these by the route just indicated; it produces from the blood a digestive fluid which forms part of the bile and passes by the same route; it removes surplus food from the blood, storing it in its own cells and later returning it to the blood; and there are also certain forms of waste matter which it takes up from the blood, changes and returns to the blood in such form that the kidneys can remove them.

All the excretory organs—lungs, kidneys, liver, and even the intestine—are built on much the same general principle. In all, there is a spreading out of the blood stream into capillaries

in the walls of tubes which lead to the exterior of the body. The excretory organs act to remove wastes from the blood, and not directly from the tissues; the blood takes up the wastes from the tissues and therefore needs purification. The organs of excretion never extract *all* the wastes from the blood, but only the excess above a certain percentage which is a normal content of the blood.

In discussing the blood, some chapters back, we noticed the remarkable fact that it remains at a nearly uniform composition, in spite of the varying influences to which it is subjected. During muscular activity it contains scarcely any more carbon dioxide than during rest, for the increased production of carbon dioxide in the muscles is offset by more rapid breathing and circulation. After a meal rich in carbohydrate food, which is reduced to glucose in digestion, the blood contains scarcely more glucose than at other times; for the liver stores up the excess, and if any of the excess gets past the liver, the kidney takes it and passes it into the urine. In several other cases as well, the liver and kidney thus coöperate to remove an excess of wastes or even of food components of the blood.

After a meal, there is of course an excess of

food substances in the blood coming from the intestines. There is a temporary surplus of food, which will later be needed for heating the body and supplying its energy, and also for making good the slow waste of the tissues. The surplus is stored, and it is important to know something of the body's facilities for storing surplus food, since this is a matter that bears very directly on the question of a proper diet.

The storage of carbohydrate has already been several times mentioned. The liver stores up sugar, changing it for the time being to a starchy form, and later doling it back into the blood as sugar—as glucose, to be more precise. A minor storage of sugar occurs also in the muscles. Carbohydrate storage is short-time storage. Large quantities of this sort of food are readily stored, and quickly given up again to the blood, as the muscles require it. After hard muscular work, or after a day or two of fasting, very little carbohydrate is left in storage. "Easy come, easy go" is the way with carbohydrates; they are readily digested, and readily burned. Especially sugar requires very little digestion; and athletes sometimes take sugar in the midst of a long strain, thus getting new fuel very rapidly into their muscles.

Fat, coming from the intestine, is stored to some extent in the liver and to some extent in various other tissues, but accumulates for the most part in special layers of fat beneath the skin and in some of the spaces between the internal organs. These are the great fat stores; and this storage of fat, in contrast to that of carbohydrate, is a long-time storage. A few hours' exercise, or a day or two of fasting, makes but slight impression on the fat stores. Many people know to their sorrow how hard it is to work off, *i.e.*, to burn up, an excessive store of fat. Fat is, in fact, a very concentrated fuel, and at the same time it is less readily burned by the body than the carbohydrate. Whatever carbohydrate is present in the body is burned first, and then the fat stores are drawn upon. The fat stores, with their large supply of potential energy, are insurance against famine. In the primitive conditions of wild life, the food supply is irregular, sometimes overabundant and again deficient; and the way of wild animals is to eat all they can when they find it, so fattening themselves up against the time of scarcity. A deer may be sleek and fat in summer, and quite emaciated at the beginning of the following spring; it has lived through the winter partly on what it

ate the summer before. Wild tribes of men alternate between similar extremes of plenty and famine, of corpulence and emaciation. In civilized societies, the regular provision of food, day by day, makes the fat stores much less important in bodily economy. Illness, indeed, may enforce a period of fasting, and then the fat stores prove of great value. But, on the whole, civilized man is prone to overdo the matter of fat storage. He is a miser in this respect, taking all he can, *i.e.*, eating all his appetite will permit him, and giving out as little as possible, *i.e.*, leading a life of muscular inactivity. This miserliness is agreeable for a time, and gives a man a well-fed and prosperous appearance; but it is apt to lead too far, and leave him with a white elephant on his hands. It is less conducive to health, vigor, and long life, than a more abstemious and more active life, in which the intake and the output of fuel or energy balance each other, so that the individual remains, not thin, indeed—perhaps slightly fat—but nearly uniform in weight from year to year and from decade to decade.

Not all the fat stored has been eaten in the form of fat; but some of it has been manufactured by the body from carbohydrate or protein. Animals are fattened for the market by feeding

them on starchy foods. It appears, then, that, when a meal of carbohydrates has been digested and absorbed, most of the carbohydrate is stored in the liver for immediate use, while a small portion is transformed into fat and stored in various parts of the body against a time of want.

Protein also is stored by the body, but not in large quantity, nor in any special organ. Since this substance is an essential part of the living structure and machinery of all cells, its presence there is not to be regarded as storage. If, however, protein is abundantly eaten, the cells take up more than is necessary for their essential structure; and if then a period of fasting succeeds, they give out to the blood some of their protein without losing any of their essential structure, and without being weakened by the loss. If the fasting continues too long, indeed, and the fat stores of the body are used up, then the essential protein of the cells is drawn upon, and the tissues become wasted and weak. Whether it is possible to draw a sharp line between the essential protein of cellular structure and extra protein stored in the cells, is rather doubtful; but there is no doubt that, with abundance of protein in the food, the cells store a certain amount.

But, as was said, the amount of protein stored is comparatively small. What happens when large amounts of protein are eaten is quite a different story from what has just been told regarding the carbohydrate and the fat. It will be recalled that protein is a very complex substance, and differs from the other foods in containing the element nitrogen. Now when large amounts of protein are eaten and absorbed, the protein is quickly split up into a nitrogen-containing part and a part which contains no nitrogen and is essentially similar to carbohydrate. The carbohydrate portion is then stored in the liver, as usual, or part of it may be in turn converted into fat; but the nitrogenous portion is quickly eliminated by the kidneys. It appears that more than a certain small amount of nitrogen is of no service to the body and is gotten rid of as soon as possible, being treated as a waste. The story of protein is then as follows: a small amount is needed for the building and repair of cellular structure; a little more is stored by the cells; and the remainder of what is eaten is treated simply as fuel, and is quickly deprived of its nitrogenous portion as if this were undesirable. The eating of large amounts of protein food is thus seen to be uneconomical, first because

protein is expensive, and second because extra work must be done by the body to split off the nitrogenous portion of protein and to eliminate it from the body.

The chief nitrogenous waste of the body is *urea*. This is the principal ingredient of the urine, aside from the water in which the urea and other wastes are dissolved. (Urea has a much simpler molecule than protein, or even than the amino-acids which compose the protein molecule; but it still contains the NH_2 radicle.) Urea is formed by the liver from more complex forms of nitrogenous waste which are formed in all the organs and carried by the blood to the liver. The urea present in the urine comes partly from unavoidable tissue waste, and partly from the excess protein of the food, which has been split up as described in the preceding paragraph. Another nitrogenous waste, excreted by the kidney, is uric acid, formed from the nuclei of the cells, and also from nucleoprotein eaten. Excessive formation of uric acid seems to be a factor in the causation of gout.

The liver and kidney ordinarily perform their functions without need of intelligent control, and there is little to be said in the way of advice regarding them. Continued use of alcoholic

drinks tends to weaken them, causing degeneration of their cells, and making them more susceptible to the attack of disease. Continued over-eating also acts harmfully on the liver, perhaps because of the excessive work thrown upon it. Severe chilling of the back sometimes injures the kidneys, and great anxiety or mental shock seems sometimes to affect the liver. In general, the rules for preserving the health and normal function of these organs are simply the ordinary rules of health and moderation.

That other organ of excretion, the intestine or bowel, is more in need of attention and intelligent control. The wastes eliminated by way of the intestine come partly from the liver, and partly from the blood directly into the intestine; in part, also, they consist of indigestible portions of the food. Further, the mouth, throat and intestine always contain bacteria, and the waste products of these bacteria must be removed. It follows that the evacuation of the bowel is a very important factor in keeping the body free from harmful substances.

Constipation, or insufficient evacuation of the bowel, is a common complaint, and serious enough to deserve particular attention. When the food—which at this late stage of its passage

is mostly waste—is allowed to remain too long in the large intestine, some of the injurious substances already present in it are reabsorbed into the blood, and other injurious substances are formed there in the large intestine by the action of putrefactive bacteria, and are absorbed into the blood and carried to all the organs. Feelings of depression, unfitness for work or enjoyment, result from the action of these substances. The general level of health is lowered, and susceptibility to infectious diseases is increased.

Occasionally constipation is a symptom of some disease requiring medical advice and attendance; but usually it is to be avoided less by medicine than by the individual's personal attention to certain matters of diet, exercise and dress.

Some persons are so careless in the matter of regular movement of the bowels that they let days go by without even noticing whether this important function has been performed. Once a day is a good general rule, and there should be a regular time of the day, which should not be allowed to pass without at least a serious effort to induce evacuation. If the effort is unsuccessful, the fact should be noted for future reference, and any call from the bowels during

the remainder of the day should be promptly obeyed. If the day passes without a movement, it may be well to take a laxative before retiring; and, at any rate, if the regular time passes on the second day, still without success, the laxative should ordinarily be taken. Each individual should be acquainted with some mild drug, which acts strongly enough without tending to renew the constipation afterwards. Cascara sagrada can usually be recommended for this purpose.

Even a movement of the bowels once every day does not always mean complete freedom from constipation. If the stools are always dry and hard, the probability is that they have remained too long in the bowel. The removal of the waste may be continually a day behind the proper time.

The proper regulation of the bowels is impossible by mere attention to the act of evacuation, and it cannot be satisfactorily accomplished by the frequent use of drugs. To reach a really satisfactory condition of affairs, the diet must be chosen with reference to the work and preferences of the intestines. Constipation means either sluggishness of the muscular wall of the intestine, or too great dryness of the contents. To regulate the intestines by means of the diet,

one should drink plenty of water, and one should include foods that are stimulating to the intestinal muscles.

Water is contained in nearly all foods, and in fruits and vegetables it is very abundant. It is also the chief ingredient of all drinks; but alcoholic drinks and tea and coffee are not good substitutes for plain water, from the point of view of the intestine, because these beverages contain substances which, by extracting water from the blood, cause the blood to absorb all the water possible from the intestine, and so leave the contents dry. Milk also has usually a constipating rather than a laxative effect. The drinking of plain water, in addition to what is contained in foods, is certainly to be recommended. Water should not be used to wash down unchewed food, but it may properly be drunk with the meals, as well as between them.

For stimulating the intestinal muscles and preventing a constipated condition, one of the most important ingredients of food is cellulose. This is the fibrous material of plants, and occurs in roots, stalks, leaves, fruits and seeds—in short, in nearly all fruits and vegetables, as they are eaten. Though a form of carbohydrate, cellulose is too tough for human digestion, and is of

no use as a tissue-builder or as a fuel. But it has the valuable property of exciting the movements of the intestines. Foods that contain cellulose are laxative, and should be included in the diet. This means, in practice, that fruits and vegetables should form part of the daily ration. The coarser kinds of bread also contain cellulose.

Water and cellulose, then, may be called physiological as opposed to medicinal means of regulating the bowels.

Exercise is valuable for the same purpose, partly because of its stimulating effect on the entire system, and partly because it acts to churn the contents of the abdomen and arouse the bowels. Exercise in which the abdomen is turned and twisted is specially effective. A tight belt or corset acts in the opposite direction, compressing the bowels, restraining their action, and tending strongly towards constipation. The abdomen, containing as it does such important organs as the liver, kidney, stomach and bowel, should not be encased in a rigid box and so made sluggish; on the contrary, it should, by suitable gymnastics, be kept a muscularly active and efficient part of the body.

CHAPTER VIII

DIET

What goes on inside a person's body is largely beyond his direct control, but there are two or three ways in which he has something to say about it. He can control the intake of food; he can control muscular and mental activity; and he can avoid infecting his body with the germs of disease.

The practical application of the preceding chapters on the blood, digestion, and excretion is mostly to be found in the regulation of the diet. Here is one of the chief opportunities to apply scientific knowledge to the preservation and improvement of health. No doubt good health is enjoyed by many persons who know nothing of the science of food; and the natural appetite can be relied on to a large degree in deciding both how much to eat and what sorts of food to eat. Were this not so, a healthy body would be an unusual accident, for few have any intelligent comprehension of the uses of food, and even the most advanced scientific students have much

still to learn. But it would be a mistake to conclude that science has nothing to do in the matter, or that the diet of people is already so perfectly adjusted to their needs that no intelligent control is demanded. If we look over the population of civilized countries, we find many cases of defective nutrition—people who are too thin or too fat, constipated, anemic, gouty, dyspeptic, or suffering from undefined ill health which may probably be the result, in part at least, of unsuitable diet. The population of a town would not compare favorably with a well-fed herd of cattle. If the people of a town or nation were marshalled before an expert, like a farmer's herd, the expert could not give unqualified approval, but would be compelled to say, "You are not treating these animals right; either you are not feeding them scientifically, or you confine them too much to their stalls; or you allow them to be worried and to lose their proper rest; or something of the sort is the matter, for your herd, taken as a whole, is certainly not up to the best standard." Since science has proved to be of much value in the feeding of cattle, there is every reason to believe that it will be of value in the regulation of human diet—in spite of the difficulty that it is harder to get hold of the house-

keeper, the boarding-house keeper, and the hotel manager, than it is of the farmer; and, further, that the caprices of the human animal are harder to control than those of cattle.

The fundamental requirements of a good diet are obvious to common sense. Evidently the diet must be:

1. Sufficient,
2. Economical,
3. Free from injurious substances.

If sufficiency were the only requirement, the problem would be too simple to demand much science in its working out; you could simply advise every one to eat all they could get and everything they could lay their hands on. To discover what substances are injurious demands scientific investigation; but the real crux of the problem is the requirement of economy. The diet needs to be economical for the pocketbook, and it needs to be economical for the body. Since some kinds of food cost much more than others, the problem arises whether the cheaper kinds will meet the body's needs, or how much of the more expensive kinds should be added. The science of nutrition is able to show many ways in which money is spent on expensive foods without any corresponding gain to health. But it

is even more imperative to observe the requirement of economy in the inner workings of the body. It is poor economy to load the stomach with a mass of food greatly in excess of the body's need; it is poor economy to eat food that is very hard of digestion, or that throws excessive work on the organs of excretion or on the inner processes of nutrition. An economical diet, from the body's point of view, is one that supplies sufficient nutriment without requiring an excessive amount of work to be done on the food itself, in order to fit it for use.

Since too much food is a disadvantage, only less than too little, the science of nutrition must discover how much is a sufficiency. It must tell us for what purposes the body needs food, and how much it requires for each purpose, and then must proceed to tell what diet will meet these requirements with a maximum, or at least a reasonable degree of economy both to the body itself and to the pocketbook.

It will be recalled, from a previous chapter, that the body makes two uses of food. Some it needs to build up and repair its substance; and some it needs to supply energy for its activities. The quantity required for tissue building and repair is rather small, while the quantity re-

quired for fuel varies considerably, according to the amount of muscular work performed, and according to the amount of heat that must be produced in the body to keep its temperature up to normal. Brain work uses up but little fuel.

The fuel requirement of the body is best stated as such a quantity of energy, and it is usually expressed in terms of "calories."[1] An adult man of average size, and taking moderate exercise, uses up about 3000 calories of fuel-energy per day. This amount would be supplied by about 12 ounces of lard, or by 26 ounces of sugar, or by about 29 ounces of dry gelatin. These are nearly pure examples of fat, carbohydrate and protein, though the gelatin is not quite clear protein. The fuel requirement would be met by a small quantity of fat, because fat is, as explained on a previous page, a more concentrated form of fuel than either carbohydrate or protein. The fuel values of carbohydrate and protein are nearly equal, provided both are measured perfectly dry. In food, of course, protein is never eaten dry, and carbohydrate and fat, also, are seldom taken perfectly dry and clear. Consequently the above figures

[1] A "calorie" is the amount of heat necessary to raise the temperature of one gram of water by one degree centigrade.

give but little notion of the amount of food that should be eaten to supply the fuel requirement of the body. But the fuel value of every variety of food has been measured, and it is possible to state how much of any sort would be needed for a day's supply of fuel, if that sort of food were taken alone; and also to assign the fuel value of any mixed diet and determine what proportions and quantities give a sufficient supply. For example, the following quantities of different foods would each furnish the day's requirement of fuel for a man of average size, taking a moderate amount of muscular exercise. The weights given represent the food as actually eaten and do not include the inedible portions.[1]

Butter	14 ounces
Almonds or walnuts	1 pound
Smoked bacon	18 ounces
Cheese	1½ pounds
Raisins, dried figs or dates	2 pounds
Bread	2½ pounds
Beef	3 pounds
Baked beans	5 pounds
Eggs	5 pounds (or about 38 eggs)
Bananas	7 pounds
Potatoes	8 pounds
Fish	7-13 pounds
Milk	9½ pounds
Apples	10½ pounds
Oysters	13 pounds
Onions	14 pounds
Cabbage	21 pounds
Tomatoes	30 pounds
Lettuce	35 pounds

[1] The table is extracted from a much more extensive one, issued by the U. S. Department of Agriculture, as "Bulletin 28, Office of Experiment Stations."

These great differences between the fuel value of different foods depend very largely on the proportions of water and of fat which they contain. Nuts contain little water and much fat, and have a very high fuel value per pound. Dried fruits contain little water, while fresh fruits contain much. Fish are watery and oysters even more so, and tomatoes and lettuce are so to an extreme degree.

It does not by any means follow from these figures that the foods that are more concentrated fuels are therefore necessarily more economical for the body. If a food is dry, water must be drunk in greater amount than if the food is itself watery, so that the stomach contents may be about the same in the two cases. The more watery foods have even some advantage, because the food substances contained in them do not have to be softened with water in the stomach. There are, however, great differences still remaining between the different foods. It would be quite impracticable to obtain the requisite amount of fuel from such things as lettuce or tomatoes alone, or even from oysters.

Any number of combinations might be made which would satisfy the fuel requirement. For example, one pound of bread with half a pound

of butter would very nearly give the 3000 calories, and the deficit could be made up by a few nuts or raisins, or a small piece of meat, or an egg, or a glass of milk, or a little fresh fruit or vegetables. This is only intended as a sample of the possibilities. It should be noted that a person with a healthy appetite will find no difficulty in meeting the fuel requirement of his body, even if he must live cheaply.

But the more complicated question of supplying the requirement of tissue-building food has to be considered. Since nearly all forms of both animal and vegetable food contain some of all necessary ingredients for tissue building and repair, it would be possible to obtain sufficient of everything by taking a large enough quantity of almost any food. But this would often be very uneconomical, for to get a sufficiency of some tissue-builder it might be necessary to consume great quantities of the food and so to throw much unnecessary labor on the organs of digestion and excretion. The body would rebel, and would signify its disapproval by loss of appetite and digestive disturbance. Bodily economy requires that the necessary supply of all tissue-builders should be obtained without much increasing the fuel value of the food. All re-

quirements should somehow be met without exceeding the fuel ration of 3000 calories for a man taking a moderate amount of muscular exercise.

The chief tissue-builders are protein, phosphorus (in combination), iron (also in combination), and salts of several kinds, among which the salts of lime or calcium most deserve attention. Lime salts form the bulk of the bones, and exist also in small quantities in all cells and fluids of the body. A good supply of lime in the food is specially needed during the period of growth, because of the demands of the bones. Iron is needed for the hemoglobin of the blood, and phosphorus for the nuclei and other essential parts of the cells, as well as (in composition with calcium) for the formation of the bones.

Examination of the actual diets of many families shows that there is seldom any deficiency of protein, but that a deficiency in iron, calcium or phosphorus is not altogether uncommon. Poor health may often be the result of such deficiencies. The different sorts of food differ greatly in the amounts of these necessities which they contain. In general, vegetables are rich in phosphorus, iron and calcium, and this makes up, to a large extent, for their low fuel value. Spinach is remarkably rich in iron, and carrots, tur-

nips and parsnips in phosphorus and calcium. Other foods which deserve special consideration here are milk (and cheese) and eggs. Milk is very rich in calcium, so rich, in fact, that when it enters considerably into the diet, little anxiety need be felt about meeting the body's need for calcium. Milk is also rich in phosphorus; but it is poor in iron. It is a remarkable fact that the new-born child brings with him into the world a supply of iron sufficient to last him for the sucking period. After that, the continuation of an exclusive milk diet tends to anemia. Eggs are rich in iron and phosphorus, and are not deficient in calcium. Wheat grain is rich in iron, but most of this is contained in the outer layers of the grain, which are excluded from fine white flour, with the result that bread, as we eat it, is rather weak in iron. It does not follow, of course, as promoters of patent foods sometimes assert, that eating of white bread is weakening to the body; this would only be the case if bread formed the only article of food. What is lacking in bread can easily be supplied from some other source, such as vegetables. In general, it would seem that whoever includes milk and a variety of vegetables in his diet is pretty sure to supply a sufficient quantity of the tissue-builders.

8

The question of the protein supply, however, still awaits our attention. Since protein enters into the structure of all living cells, it forms part of all foods, animal and vegetable, except some that are specially prepared, such as butter, lard, olive oil, starch, sugar and syrup. But some foods contain a much larger proportion of protein than others; meats and fish, eggs, milk and cheese, peas and beans, and nuts contain it in abundance, while most fruits and vegetables contain but little of it. Bread occupies a middle position in this respect.

The first question is, as to how much protein is daily needed by the body; and this question is as yet far from exactly settled, and is, indeed, a question that is just now being much debated among scientific students of diet. Some would place the daily ration of protein at about 100 grams of the dried substance, and others at about 60 grams. The larger allowance would be contained approximately in 1 pound of lean beef, or in 2½ pounds of bread, or in 3 quarts of milk, or in 3 pounds of baked beans. This larger allowance corresponds roughly to the amount of protein found to be habitually eaten on the average—though it should be said that this allowance is often considerably exceeded. The smaller

allowance is not based on the actual habits of men, but on experimental studies directed to finding out what is the minimum requirement.

The experimental studies have approached the question in the following manner. Evidently no diet would provide sufficient protein if it did not make good the loss of protein from the body through tissue waste. If there were a continual excess of protein lost over protein taken in, the tissues would be slowly starving, no matter how much carbohydrate and fat might be eaten. A man would certainly starve to death on a diet entirely lacking in protein, or on a diet containing only a very little protein. In growth, or in recovery from illness, the body should lay on protein; and in adult life, the intake of protein should balance the out-go, so that the body should remain in protein equilibrium, or, as it is also called, in nitrogenous equilibrium. In other words, the nitrogen taken into the body in the food should be equal in amount to the nitrogen excreted from the body (mostly by way of the kidneys). Now when the in-take and out-go of nitrogen are measured in a man who is living on a diet rich in protein, to which he has been accustomed, he is found to be in nitrogenous equilibrium. If then his diet is made somewhat

less rich in protein, he loses for a few days more than he takes in, but gradually comes to equilibrium again, at a lower level. He now has less protein stored in his body, but has probably not lost any of the essential protein of cell structure. If the protein in his food is once more diminished, the same thing is repeated. He loses some protein, and then comes to equilibrium. By gradually diminishing the protein in the food, it has been found that equilibrium can be established, for an active healthy man, with as little as 60 grams of protein in the daily ration, and indeed with rather less than this. If the man became weak or evidently suffered from poor nutrition as the result of a prolonged experiment of this sort, the inference would be clear that his protein food had been reduced to too low a figure; but the experiments were continued for several months without any indication of bad results. Therefore, it was urged, the necessary ration of protein is not over 60 grams per day, and this is much less than most men in Europe and America, at least, are accustomed to eat.

This experimental work is recent, and the results of so low an allowance of protein have not been tested over long periods of years. Some critics of the work urge that the vitality of the

body may be impaired by running on so low an allowance; and that it is probably best to maintain the body's store of protein at a rather high level. On the other side, the advocates of the low protein allowance, among whom Professor Chittenden of Yale is the chief, declare that they feel better on the low allowance, and are free from a variety of minor ailments and symptoms of imperfect health; and they contend that the low allowance is more healthy than the old standard of 100 grams.

Another point is brought into the argument. It will be recalled from the preceding chapter that, when a meal rich in protein is eaten, most of the protein is quickly split up in the body into a nitrogenous portion, which is eliminated by the kidney, and a non-nitrogenous part, which is similar to carbohydrate and is stored and used as fuel. The nitrogenous part seems to be of no service, except for a small quantity of it. Now it would seem that this splitting up of protein, and rapid elimination of its nitrogenous portion, was unnecessary labor, since the fuel could be equally well obtained from carbohydrate, which is more readily digested and does not need to be split up and partly eliminated without use. Protein food seems to throw unnecessary labor on the

kidney and liver. It may therefore be best to cut down the protein as much as possible, in the interests of internal economy. On the other hand, it may reasonably be replied that a moderate excess of protein above the minimum requirement can hardly do any real harm to the liver or kidneys; for no organ appears to be injured by a moderate or even considerable amount of exercise. It is not necessary to take care that the muscles, or the heart, or the brain, do no more than the least possible amount of work; and probably it is not necessary to protect the kidney from doing considerable work.

The fact is that all the arguments on both sides of the question, as between the lower and the higher allowance of protein, are weak and uncertain. We do not yet know which is better. But so much as this may be admitted: that there is no known necessity for a high allowance, and that the probability is that mankind is prone to indulge in protein more than is necessary or economical. Many individuals certainly eat excessively of meats and similar protein foods, and lay up trouble for themselves in the shape of gout or disturbances of the liver and kidneys.

The practical outcome of the whole discussion is that there is little danger, as diets go at the

present time, of getting too little protein, while there is some danger of excess, especially if one is fond of meats and other foods containing much protein. It is not difficult to count up 100 grams of protein in the day's food of most men. For example, if a man eats, in the course of the day, ½ pound of bread and rolls with ¼ pound of butter, 2 ounces of cereals, 1 pint of milk, 1 plate of soup, ¼ pound of lean meat, and ¼ pound of puddings or pies, he has provided, in these articles alone, about four-fifths of the 100-gram ration of protein, and also four-fifths of the 3000-calorie ration of fuel. When this point has been reached, there will be no danger of any injurious deficiency of protein, for vegetables can be depended on to make up a considerable share of the remainder while such odds and ends as an egg or a piece of cheese or a few nuts count up rapidly in the protein column. A healthy appetite, not forced in the least, can usually be relied on to give a correct measure of the total amount of food to be eaten, that is to say, of the fuel ration; while the inclusion in the day's food of a moderate amount of foods with high protein content, such as meat, fish, eggs—along with a good supply of the staff of life—can be depended on to bring up the protein above the danger point.

The fuel requirement increases with the amount of muscular work performed, and in cold weather, and is decreased in hot weather and by a strictly sedentary life. The protein requirement is not affected by these conditions, since any increased need for fuel can be met perfectly well by fat and especially by carbohydrate.

It is clear, from all that has been said, that the most economical diet for the body is a diet that is decidedly mixed. A diet composed mostly of meat would contain a large excess of protein, with a large amount of nitrogenous waste to be eliminated. A diet composed wholly of bread and butter would largely exceed the fuel requirement in order to supply the requirement of protein. A diet composed exclusively of vegetables would be enormously bulky. Man is best treated as a distinctly omnivorous animal, and his diet should be partly of cereal foods, partly of vegetables, and partly of meat and other animal foods.

A mixed diet is the safest reliance for supplying sufficient quantities of all the tissue-builders, previously discussed, and for supplying the requisite fuel; and it is also the most economical from the point of view of the organs of digestion. In two respects it is best for digestion:

it is, in the long run, the most appetizing and therefore the most stimulating to the flow of the various digestive juices; and it utilizes most completely the powers of these juices. It is found by experiment that the digestive organs do more efficient work on mixed food than on unmixed. It is found that when a meal is composed of only one sort of food, it is not completely digested and absorbed into the blood, but is partly passed out as waste from the intestine, whereas mixed foods are almost completely utilized. The reason for this is easy to see. We found in studying digestion that enzymes were present in the various juices, each suited for the digestion of one sort of substance. If then any sort of substance is not present in the food, some of the enzymes are of no use, and the full power of digestion is not utilized. Unless some starch is present in the food, the saliva has no digestive action, but simply lubricates the morsels so that they can slip easily down the gullet. Unless some protein is eaten, the gastric juice has no chance to do its digestive work. Unless some fat is eaten, the bile is of no service in digestion. If any one juice, or any one enzyme, is unable to perform its function, more work is thrown on the other enzymes, and the difficulty of diges-

tion is increased. The most economical diet, from the point of view of the stomach and intestines, is clearly one in which proteins, fats and starches are all represented. Sugars also should be included, on account of their very easy digestion. To eat sugar does not necessarily mean to take it clear, as a lump, or as syrup, candy or honey; for there are many other ways in which it can be taken. On account of the well-known tendency of sweet things to take away the appetite, they are properly left to the close of the meal. Sometimes, however, the thought of the sweets to come takes away the appetite for the other parts of the meal, and so may lead to taking insufficient protein, iron, etc. Though much is said against the eating of candy and similar sweets, it is unlikely that they do any harm except as they prevent the eating of a sufficiency of other foods.

Meat is a subject on which extreme views are often expressed. Some people seem to regard meat as *the* food, all others being accessory. Meat they speak of as "good, strengthening food," while other articles of diet are little more than so much stuffing. The science of nutrition does not support this view. It is true that meat is one of the best sources of protein, since it is

more readily digested, more completely absorbed, and perhaps more easily utilized by the body than the proteins of vegetable origin. Its advantage in this respect is not, however, great enough to be very important. Another advantage possessed by meat is that it is specially appetizing, and excites the gastric juice more strongly than most other foods. But both of these advantages can be secured without the consumption of large quantities of meat. Only a little is needed as an appetizer, and only a little is needed to supply protein, since the protein requirement of the body is small compared with the need for fuel. The muscles and other living tissues can not be forced into rapid growth by piling on the protein; they grow as nature intends, and according to the exercise they get. The energy for muscular work, the fuel, in other words, can be supplied quite as well by carbohydrate food. From all that we know about the use of food by the body, we conclude that meat should not form the bulk of the food, but should be taken in moderation.

But while some people err on the side of exaggerating the importance of meat, others err on the side of condemning all meat as essentially harmful. The vegetarians are very

eager to argue the case, for they think that they have arguments of conclusive weight. They say, for one thing, that flesh is foul with harmful wastes. This is pure assertion, and is not borne out by the facts. Animal flesh is very similar to human, and to take in some animal flesh is no worse than to carry around a large mass of human flesh. Flesh of healthy animals, properly safeguarded after slaughter, is as pure and free from poisons or the germs of disease as any ordinary food. But, the vegetarians say, think of where this meat comes from, and what it is made of! Especially think of what pork is made! Well, good fresh garbage is not to be scoffed at, by a pig. You would have eaten some of it yourself, if your appetite had been a little better, for then you would not have left what you did on your plate. One minute, a morsel is a bit of delicious food waiting on the plate to be eaten; the next, it is foul garbage removed from the table and thrown to the pig. Fortunately the pig is not so capricious, and so, to quote an unnamed economist, "What you can't eat you give to the pig, and then you eat the pig." Vegetable foods have an even more humble origin than animal, for they are built up from carbon dioxide and manure, the very wastes

of animal existence. This whole argument of the vegetarians is a pure matter of sentiment, which disappears in the light of an adequate conception of the processes of the body and of nature in general.

They present also the argument from inhumanity. They feel it to be cruel and unworthy of mankind to take the lives of anything but vegetables. Man should not be a tiger or wolf, but a gentle deer or cow. These people, in their zeal for animal welfare, would actually have us exterminate the most important domestic animals. No farmer is likely to raise a herd of cattle for the pleasure it gives the cattle; but, because there is a demand for their flesh, he causes them to multiply abundantly, provides verdant pastures in which they may graze, shelters them from the piercing blasts of winter, and finally fattens them on all the corn they want to eat. The few seconds in which each one meets the agony of death are as nothing beside the months spent in contentedly chewing the cud. What an enlightened love of animals should strive for is not the disuse and consequent extinction of domestic animals, but kind treatment.

From a broad economic point of view, indeed, it appears that the use of meat must gradually

decrease. To produce a pound of meat, many pounds of vegetable food must be fed to the animal, and most of this food, like that of a man, is burned as fuel, only a small portion remaining over as flesh to be eaten. The same ground that supplied food for the cattle could be used to raise vegetable food for man, and would thus yield a much greater supply. As the human race increases and settles the world more densely, the raising of meat must become more expensive, and its use more restricted. But such a change in human diet will be attended by many other changes. Substitutes must be found for other animal products besides meat—for milk, cheese and butter, for wool and leather, and for the fertilizer of animal origin that is now returned to the soil to increase the production of vegetables. Human ingenuity and human science may be able to solve these problems; but, as far as our knowledge reaches to-day, we have to count ourselves fortunate in living in a time of comparative plenty, when it is still possible to use a little animal food, and so, in effect, to let the animals do for us part of the work of reducing vegetable proteins to the forms that are most easily utilized as tissue-builders for man.

It will of course be understood that this chap-

ter gives but a rough sketch of the science of food and nutrition. It has aimed to tell about as much as could be easily applied in practice by one who, having nothing to do with the preparation of food, is concerned only to select from what is offered in about the right quantity and proportions. The housekeeper may well go into the subject more deeply, especially in view of the fact that substantial economies, from the financial point of view, can often be attained without the sacrifice of any real food value. It seems probable that the housekeepers of the next generation will be trained to a scientific knowledge of the needs of the body and the best means of meeting them. Any one who would go further into this very interesting and practical subject can now find excellent books,[1] not too difficult of comprehension, that give a thorough treatment of the chemistry and physiology of nutrition.

[1] One of the best is the "Chemistry of Food and Nutrition," by Professor Henry C. Sherman

CHAPTER IX

BODILY HEAT

One of the most remarkable powers of the body is that of maintaining a constant internal temperature, in spite of the differences in external temperature to which it is exposed. As measured by the thermometer, the temperature of the mouth (under the tongue) is 98.4° Fahrenheit, and that of still more internal parts is a fraction of a degree higher. The skin, of course, being directly exposed to outer influences, is usually colder than this, and more variable. In health, the temperature of the interior of the body varies only within very narrow limits.

Now this constancy of temperature is not found in all animals, but only in a small minority. All invertebrate animals, including insects, crabs, molluscs, worms, starfish and a host of others, and many vertebrate animals as well—fishes, frogs, reptiles—are known as "cold-blooded," not because their blood is always cold, but because it has approximately the same temperature as the air or water in which they live,

and varies with the external temperature. The "warm-blooded animals," which maintain a constant temperature, include only birds and mammals, the latter class comprising those animals which have hair or fur, which suckle their young, and which we commonly know as the "beasts." Man is a mammal, rather deficient in fur, the lack of which he supplies, in cold climates, by artificial coverings.

A few words will make clear the utility of the constant temperature of warm-blooded animals. All the activities of living cells, and of enzymes as well, go on best at about a certain temperature, which is not far from that of the human body. Lowering the temperature below this point decreases the activity of the cells, and lowering it to near the freezing-point makes them almost entirely dormant; while raising the temperature much above 100° first makes the activity excessive and hard to control, and then destroys the cells and enzymes. A constant temperature of about 100° enables the cells to be fully active at any time, without regard to the external conditions. Animals which do not possess this power of maintaining a constant temperature become sluggish in cold weather, and at the approach of winter creep into holes or bury themselves in the ground,

so as to avoid actual freezing, and pass the winter in a state which is much more dormant than that of sleep. Even some mammals, as the bear, the bat and several others, do not maintain their temperature during the winter, but are said to hibernate. Creeping into some sheltered place, they go to sleep, and more than go to sleep, for their temperature sinks to near that of their burrows, and their activity diminishes to almost zero. Even breathing and the heartbeat almost cease, so that the hibernating animal consumes his store of fat and other body fuel very slowly and gets through the winter on what he ate the previous summer. Thus he is relieved from the necessity of struggling for fresh fuel when food is scarce. Many human individuals would like to develop this power of hibernation, but it is not within the capacity of man, who suffers serious injury if his temperature sinks much below the normal. Those animals that maintain a constant temperature in the winter are able to continue their full activity throughout the year.

To understand how an animal can maintain a temperature higher than his surroundings, one may recall how it is that a house is kept warmer than the air outside. Two things are necessary: a fire within the house, and good walls to pre-

vent the heat from escaping rapidly. Now the warm-blooded animal is protected from too rapid escape of heat by a layer of fat beneath his skin, and usually also by feathers or hair, or in case of man by artificial clothing. The internal source of heat is provided, in the body, by the combustion of food. It has already been said that food, by uniting with oxygen, supplies the energy necessary for muscular movement and for all the bodily activities. But a large part of the food consumed, and usually much the largest part, goes to the production of heat. The body's furnace is not located at any one point, since every organ, when active, generates heat. The greatest heat-generators are the liver and the muscles, and among the latter the heart and the muscles of breathing deserve special mention as steady producers of heat.

Grant that heat is produced by the burning of food, and that it is hindered in its escape by the fat layer of the skin and by external coverings. A still nicer question now comes into view: How is it that the production and escape of heat are so balanced against each other that the temperature of the body remains constant? The example of the house may here serve us once more. If a house, once at the proper tempera-

ture, is to be kept there, heat must be produced by the fire exactly as fast as it is lost through the walls, doors and windows. If the furnace supplied heat faster than it escaped, the house would grow too warm. If the walls and windows allowed heat to escape faster than the furnace generated it, the house would cool off. Now the house is exposed to various sorts of weather. When the weather is cold, the escape of heat is hastened, and the fire must burn the hotter. When the weather is warm, heat leaves the house but slowly, and the furnace must burn low, or else the windows must be opened to allow the heat to escape more easily.

All these remarks apply to the body. There too, the production of heat by the muscles, liver and other organs, must be exactly balanced by the escape of heat. Heat leaves the body partly in the air expired from the lungs, but mostly through the external surface. The skin loses heat in part as any object loses it when surrounded by cooler bodies, by radiation into space, and by conduction into anything that touches it, such as the air, clothes, the chair sat in, the ground stood upon, or anything held in the hand —provided always that such objects are cooler than the skin. If they are warmer, conduction

carries heat into the body, and radiation from hot objects also brings heat into the body.

But the skin is not purely passive in its loss of heat, but possesses a special means for accelerating the escape of heat when this is necessary. In the deeper layers of the skin are situated innumerable minute glands, from which little tubes or pores run to the surface. The glands have the power of taking water—and also a little salt and a little waste, but principally water—out of the blood, and pouring it on the surface, where it forms the sweat or perspiration. No doubt most people consider sweat rather a nuisance, and have little idea of its real function. It exists not mainly to remove waste matter from the body, but to cool the surface by its evaporation. Much more efficient than either radiation or conduction as a means of ridding the body rapidly of surplus heat is the evaporation of the sweat. Heat is required to convert the liquid into vapor, and this heat is supplied by the skin, which thus becomes cooled.

It will be seen from this that the evaporation of sweat is an important means of preventing the body from becoming overheated. It is in fact the only means by which the body can remain *cooler* than its surroundings. If the tempera-

ture of the air is above 98°, radiation and conduction carry heat into the body and not out of it. But by virtue of the evaporation of sweat, a man can remain for some time in the hot room of a Turkish bath, at a temperature of perhaps 150 degrees, and still maintain his normal temperature. If the air is not only hot, but damp, evaporation proceeds slowly, and for this reason the steam room of the Turkish bath cannot be at so high a temperature as the hot air room. For the same reason, a damp, hot day is specially oppressive.

Perspiration is nature's means of avoiding sunstroke. When a man who is working in intense heat stops sweating, he experiences a momentary feeling of relief, and imagines he is standing the heat better. But if he keeps on working, his temperature inevitably rises, and collapse soon follows. The stoppage of perspiration, under such circumstances, means that the heat-regulating mechanism of the body has given out under the hard strain put upon it. Deprived of this vital mechanism, a man cannot long survive.

It is certainly a mistake, and it is a common one, to regard sweating as a mere nuisance, and to do everything possible to prevent it. But the sweat does no good unless it evaporates. The

practice of mopping it off as fast as it is formed prevents its evaporation and defeats its purpose. Undoubtedly sweat has an uncomfortable feeling on the skin, but one can accustom oneself to this feeling, and come through a hot day much more comfortably if the sweat is allowed to stay and evaporate than if it is quickly removed on a handkerchief.

From what has been said, the cause of thirst on a hot day needs no explanation. Water is needed by the body for the formation of sweat. Some people avoid drinking on a hot day, because, they say, the water simply comes out on the skin, and so clearly does no good. But the reason for drinking water on a hot day is simply that it may come out on the skin,—or supply the place of the water that has already come out. Undoubtedly it is possible to overdo the matter, but water is a necessity in hot weather, especially if a man is exercising vigorously.

Perspiration becomes dangerous when the external temperature suddenly falls, because the moist surface of the body is apt to be chilled. The sweat has outlived its usefulness. Sudden changes of temperature, due either to the weather, or to going from a hot room to the cold air outside, or sudden cooling off after exercise,

are perhaps the commonest ways of catching cold.

In order to guard intelligently against colds, it is necessary to understand, as far as may be, how a cold is taken; and in order to understand this, it is necessary to review and amplify the remarks that have been made as to the means by which the body regulates its temperature.

The body of a warm-blooded animal, as has been said, needs to maintain always a certain temperature, which in man is 98° Fahrenheit. If the temperature is to remain constant, the loss of heat, by radiation, conduction and evaporation, must always keep exact pace with the production of heat. Now both the loss of heat and its production are controlled by nerves, which in turn are controlled by the brain; and the brain, in health, regulates the loss and the production so that they shall exactly balance each other. The production of heat is regulated mostly by the nerves that run to the muscles and cause them to act; for the more muscular activity, the more heat is produced. The loss of heat is regulated mostly by nerves that run to the skin. Some of these are sweat nerves, which excite the glands to pour out more or less perspiration, according as to the amount of heat to be eliminated. The sweat nerves, then, regulate the loss of heat by evap-

oration. The loss by radiation and conduction is regulated by nerves running to the blood-vessels, and causing them either to dilate and allow much blood to flow through them, or to constrict and permit only a small flow. When the superficial vessels are wide open, the skin is flushed with the blood coursing through them, and it is then that we feel warm. But it is just then that we are radiating and conducting heat off most rapidly, because the blood is conveying our heat from the interior to the surface, where it is cooled by exposure to the cooler air and objects outside.

When, on the contrary, the superficial vessels are constricted, the skin becomes pale from absence of blood, and feels cold. Yet it is then that least heat escapes, because the blood is retained in the interior, and the heat is not carried to the surface to escape. In "chills and fever," it is the surface only that is chilled because of a strong constriction of the vessels; the interior of the body, not losing its heat as usual, rises in temperature, as can be told by a thermometer held under the tongue. When the internal temperature has thus risen for some degrees, it simply compels the brain to provide for the more rapid loss of heat, by causing the skin vessels to dilate. Then the blood rushes to the

surface, and we feel the fever. But though we feel so hot, we are probably cooling off, especially if a sweat supervenes.

From the principles stated, one could easily reason out how the body would react when exposed to external heat or cold. If exposed to heat, it hastens the escape of heat, or slackens the production of heat, or both. Usually it does both. The blood is sent to the surface, and perspiration is quickened; and so heat is rapidly eliminated. At the same time, there is a disinclination to muscular exercise, and if this disinclination is followed, the internal furnace is made to burn low. By these two means, or sometimes by the first alone, the bodily temperature is prevented from rising.

Suppose, on the other hand, that one is exposed to cold. Then the loss of bodily heat is slackened by the stoppage of perspiration, and by constriction of the superficial vessels. The exposed skin and the extremities become bloodless and cold. At the same time, the heat-producing process is stimulated. The natural tendency is to stir around and exercise the muscles; and the result of this is renewed warmth of the skin from the blood rushing back to it. If a man resists the natural tendency to stir about when he is

cold, and sits still, he gets into a shiver, which is a form of involuntary muscular activity, and produces heat.

It might be supposed from this that catching cold meant a failure of the body to react properly to cold, and a fall of the internal temperature. Sometimes this may be the case. If, for instance, a man has taken a good deal of alcohol, which causes the superficial vessels to dilate, and then exposes himself to cold, he is likely to cool off below the proper temperature, and suffer in consequence. But in most cases, the body temperature does not fall much, if any, in the process of catching cold.

The usual process in catching cold seems to be about as follows. A man is exposed to cold. The proper constriction of his superficial vessels results; his hands and feet are cold; the blood is driven to his internal organs to prevent loss of heat. This is all right as a temporary reaction, but if it continues, the internal organs, and in particular the mucous membrane of the throat and respiratory passages, become gorged with blood, or "congested." This at once makes the sensitive portions of the membrane feel raw. Besides this, where the congestion occurs, a liquid oozes out from the blood and accumulates on the

mucous membrane; this too is irritating, and, when in the nose, causes sneezing. And now is the time when the bacteria begin their work, for it must be understood that bacteria are always present in the mouth, nose, throat and lungs. Usually bacteria do not accumulate in the respiratory passages enough to do any harm. But where this mucus has been poured out, they find a favorable soil for growth; and they grow and multiply, irritating the mucous membrane the more, causing still more fluid to be poured out, obstructing the respiratory passages, and very likely producing a certain amount of poison which, getting into the blood, causes the general bad feeling of a cold.

When once the bacteria have got a good foothold, it is no easy matter to get rid of them and eradicate the cold. If the cold promises to be at all serious, it is best, whenever possible, to give up to it and spend a day in bed. But to check a cold at the very outset is a much easier task. Nip a cold in the bud—that is the only good rule, unless you can avoid them altogether.

First, then, a few words about nipping colds in the bud, and then a few about avoiding them altogether.

The bud of a cold is to be defined as the time

when the cold is being caught, when the hands, feet and back feel chilly, when the throat becomes raw or the nose begins to run, when sneezing occurs. That is the time to realize that the present duty is to block off the cold. The chilly feeling must be removed, the congestion of the mucous membrane must be checked by driving the blood to the surface, the skin must be made to glow. Vigorous exercise is one means of accomplishing this result. The production of heat is thus increased, and, all danger of a lowering of body temperature being removed, the constriction of the superficial vessels will give way to dilation. Other ways of counteracting the tendency to catch cold are to go into a warm room, or take a hot bath, or cover up warmly in bed. Especially is it good to warm the feet thoroughly, and so draw the blood to them and away from the nose and throat. In some way or other, the body must be got promptly into a warm glow; and then the cold is probably nipped. But one caution must be observed. If the glow of the skin has been accompanied by profuse perspiration, the skin must be thoroughly dried before another exposure to the cold air; otherwise it may be chilled again, and another cold be caught.

Along with this care to secure a glowing skin,

another expedient should be adopted for checking a cold at the start, and that is, movement of the bowels. It would be a little hard to say what the evacuation of the bowels does to stop a cold. It undoubtedly helps by removing bacterial poisons; but probably it does more than this. Catching cold is favored by a constipated condition or other digestive trouble, and possibly the reason is to be found in a congestion of the mucous membrane, due partly to irritation from the contents of the stomach and intestines, and partly to exposure of the skin to cold. Whatever be the reason, it is certain that prompt evacuation of the bowels is a valuable means of checking a cold at the outset; and a suitable dose of medicine should usually be taken by one who feels a cold coming on.

Still another valuable precaution is to rinse the throat with one of the milder antiseptics which are recommended for gargling. Peroxide of hydrogen may be mentioned as a good one. The antiseptic kills many of the bacteria and may materially assist in checking the development of the cold.

The means suitable for nipping a cold in the bud may then be summarized as follows: Make the skin glow with warm blood, open the

bowels, and cleanse the throat with an antiseptic.

The means suitable for avoiding colds altogether, that is to say, for avoiding even the tendency to catch cold, are of course to avoid undue exposure, and to fortify the body against such exposure as is unavoidable. Neither of these precautions is so easy to take as might be supposed.

The body is fortified against exposure to cold, as against exposure to other maladies, by keeping it in a good, healthy condition. The means to secure such a condition form the subject of this whole book, and need not be detailed just here. Two things that deserve mention are the value of a reasonable amount of exercise, and the necessity of shunning digestive troubles. Often it seems as if a specially buoyant condition of health foreboded the taking of a cold a few days later, just as some sailors are said to speak of an extra fine day brewing a storm. In fact, there is some danger, when one is feeling especially well, of over-eating and so inducing digestive difficulty, and this may prove the predisposing cause of a cold.

Besides this general care of the health, a man can train himself in particular to stand a certain amount of exposure without catching cold. The

heat-regulating mechanism, like every other function of the body, is capable of training, and is trained by compelling it to work. Some exposure to cold is therefore to be recommended as a means of training the body to stand the unavoidable exposures that sometimes occur. Persons who avoid all exposure, who will not venture out on a cold day, who are afraid to bare themselves entirely in undressing, who sleep in a hot room, and who avoid the touch of cold water like poisson, become tender and sensitive to the least exposure. The normal reaction to cold—first a constriction of the superficial vessels and a driving of the blood from the skin, then exercise and increased heat production, followed promptly by a fresh rush of blood to the skin—is, in such people, only slowly and imperfectly carried out. The first step, constriction, comes promptly enough. But from lack of experience, they do not know enough to exercise when they feel cold; and even if they do exercise, the constriction is likely to persist, so that the hands and feet may remain cold for half a day after a brief exposure.

In training the body to endure cold, one should observe the rule of moderation laid down in the first chapter. It would be poor policy to catch cold to-day, in the hope of avoiding a cold at some

future time. Regularity is also a good rule here as in most other bodily functions. The thing to do is to get the body accustomed to reacting properly to exposure; it is a question of forming a habit, and everyone knows that habits are formed by repeated practice. A walk or game every day in the crisp air of autumn is an excellent preparation for the severer weather of winter.

A cold bath in the morning is found by some persons to be a valuable means of fortifying the body against catching cold. It certainly is not a necessity for this purpose, as many people are very free from colds, though they do not have this practice of cold bathing. Other persons, after giving the cold baths a trial of some years, have abandoned them without noting any change in their health or in their liability to colds. But for some individuals, at any rate, the cold plunge or shower in the morning serves as a training of the heat-regulating mechanism; it also wakes up one who is sluggish in the morning, and gets the internal furnace to burning brightly. A cold bath should be followed by the "reaction," which amounts to the second and third stages in the normal reaction to cold. The first stage is the chilling of the skin and constriction of its vessels; the second stage is muscular activity, and the

third the warm glow of the skin due to flushing it again with blood. Unless this third stage follows a cold bath, the bath has not done its work properly. If a man remains cold for an hour or two after his morning bath, either the bath is not suited to his needs, or he is not managing it properly. It is mismanagement to begin taking cold baths in the middle of the winter; the best time to start is in the summer, when the water is not very cold and feels agreeable. The practice should then be followed through the autumn, and the body gradually accustomed to the severer exposure. In winter, there is no real need of using the bitterly cold water straight from out-of-doors; but the chill may properly be taken off by the admixture of a little warm water. Another way of mismanaging the cold bath is to stay in a long time. A single good plunge is enough. Still another form of mismanagement is to enter the cold bath in a hesitating manner. To stand shivering with the feet only in the water, while getting up courage to do the whole thing, is very bad. It is especially bad for any one with a tendency to sore throat, for the chilling of the feet drives the blood to the throat, and may produce congestion. If a tub bath is taken, it is a good plan to duck the head

first by aid of a sponge or flesh brush, and then to plunge boldly in, covering the whole body as soon as possible.

In order to prevent colds altogether, not only should the body be toughened, but the causes of taking cold should be understood and avoided. Two matters of importance are the proper warming of rooms, and the judicious use of clothing.

A room in which people are to sit should be warmed so that it is comfortable to sit in, but should not be made much warmer than that. A comfortable temperature for most people is 65 or 68 degrees Fahrenheit; 75 degrees is rather too warm when the weather outside is cold, since a person sitting in this temperature is apt to perspire considerably, and on going out of doors is liable to be chilled from the cooling of his damp skin. Rooms heated to 75 degrees, or even 80 and 85, as they often are, are a source of colds. On the other hand, rooms below 60 degrees are not fit to sit in. Many colds, probably most colds, are caught in the house, either because of a general low temperature there, or because of unequal heating of different rooms or parts of rooms, or because of draughts, cold floors, etc. If a man finds himself chilly in a

room where he is sitting, and cannot heat the room, he should at least heat himself by getting up and taking a little exercise occasionally, or by putting on more clothing. A common saying is that you should never wear an overcoat in the house, or you will not "feel the good of it" when you go out. But it would be foolish to catch a cold in a poorly heated house, for fear of catching one on going out doors. If one walks briskly when out-of-doors, and afterwards has to sit in a poorly heated room, it would be more sensible to wear the overcoat in the house than outside. Still, an overcoat is not a satisfactory substitute for a well-warmed room, because it does not prevent the feet from becoming cold. It goes without saying that an overcoat should not be worn indoors when it makes the wearer uncomfortably warm, or causes him to sweat.

The great difficulty in the way of satisfactorily clothing the body for cold weather is that the same clothes are worn, and practically must be worn, indoors and out, during active muscular work and during subsequent rest. The use of an overcoat, or the removal of the jacket while exercising, is a means for avoiding this equality of clothing in different temperatures, but it is only an imperfect means. Putting on an over-

coat when going from a warm place to a cold one does not remove the perspiration from the skin and underclothes, and it is this dampness next to the skin that is the great danger. Everyone knows that when the clothes or feet are wet by rain, they should be changed, or, if this is impossible, that the body should be kept warm by exercise or by external heat until the clothing is dry. Not every one sees that clothes wet from within are as bad as clothes wet from without. So long as the dampness is there, it makes no difference whence it came. The sudden chilling of a sweaty skin or undergarment is one of the commonest ways of catching cold. The back, shoulders, and feet are the parts specially liable to a chill after perspiration. It pays therefore to observe when the undershirt or stockings are wet with perspiration, and either to change them or to take particular care to avoid exposure till they are dry.

The proper choice of underwear for use in cold weather is not a simple problem. Garments that are too thick may be the cause of colds, as well as garments that are too thin. Heavy underwear tends to cause undue perspiration in the house, and subsequent chilling of the skin by the wet garment. Cold feet may thus be the

result of heavy woolen stockings. Wool, in fact, seems to act more like a sponge than linen or cotton, especially if the latter be loosely woven. It is the air spaces in the weave, rather than the weight of the solid fiber, that obstruct the escape of heat from the body, and so protect against cold. The ideal undergarment is one that accomplishes this without acting as a sponge to hold the perspiration.

Another matter that is worth consideration is whether colds are not "catching." It certainly appears, at times, that a cold passes from one to another in a family circle, school, or office. Influenza, or the "grippe," is known to be infectious, and probably some other colds are the same. Consequently one may reasonably avoid the presence of those who are suffering from colds, and one may, with equal reason, quarantine oneself when one has a cold.

When all has been said that can be said about the avoidance of colds, it remains true that some individuals can scarcely avoid them, while other individuals, exercising no greater care, are almost free from them. Sometimes susceptibility to colds is the result of enlarged tonsils, and it may be wise to remove the tonsils. There are probably other special causes of individual sensitive-

ness, but some of them cannot be so easily removed.

The subject of catching colds has been spoken of at such length because it is a subject on which a man does not often consult the doctor, but relies on himself. He cannot have a nurse always with him to warn him to avoid the cold draughts, to tell him when his feet are getting cold from sitting in a cool room, or standing still on a wet sidewalk, or to inform him that his skin is moist with exercise or from being in a warm room, and that he must use care in going out-of-doors. He must be his own doctor in such matters. His best plan is to keep his body in so good condition, and to have it so suitably clothed, that his care about the matter shall be reduced to the minimum.

CHAPTER X

THE WORK OF THE BODY

The stomach, intestines, and other organs of nutrition supply materials to keep the body going. They do part of the work of the body. But what we ordinarily think of as work and action is performed by other organs, the arms and legs, the eyes and brain. To accomplish this work many organs coöperate, and if any of them "goes on strike," work is impossible.

Take the hand, for example, which does so large a share of human work. It consists, first of all, of a set of bones—twenty-seven in number, if we count in the wrist—all jointed together into a system of levers, and operated by cords, some of which can be seen through the skin of the wrist and back of the hand, when the hand and fingers are moved. If these cords—the sinews or tendons—are followed back into the forearm, they are found to be connected with muscles, each with a muscle of its own. The muscles have the power of moving; they can contract or shorten, and so pull on the cords,

which in turn pull on the bones of the hand, to which their ends are attached, and so move the bones and produce the movements of the hand. The shortening of the muscle can be easily noticed in the biceps of the upper arm, which bends the elbow; as it shortens, it of course thickens. The thickening is the more easily noticed, but the shortening does the work.

What makes the muscle contract? We say, *we* do it, or the will does it, or the brain does it. But the brain is some distance from the muscle, and there must be something to connect them. It is the nerves that enable the brain to put the muscles into action. The nerves are thus a necessity in muscular work. And if we ask, how the brain knows the proper time to act, we notice that the senses tell it. The sense organs, and the nerves that connect them with the brain, are as much a part of the working force of the body as are the muscles. The senses, the brain, the nerves, the muscles, the tendons, and the bones all work together, and are all necessary. If the bone is broken, the limb can make no proper movement. If the tendon is severed, the muscle cannot pull on the bone. If the muscle is wasted away, there is nothing to pull on the tendon. If the nerve is cut, the brain cannot act on the

muscle, which, left to itself, remains motionless. If the sense organs or their nerves are destroyed, the brain has nothing to arouse it to act, and remains inactive. If the brain and the other nerve centers are paralyzed, the sense organs may do their part, and the muscles be ready to do theirs, yet no movement is possible.

The muscle is like an engine; to do work, it must be supplied with fuel. This is brought to it by the blood, and therefore the heart which pumps the blood, and the blood vessels which convey it to the muscles, are as necessary for movement as the muscles themselves. As the fire needs a draught to supply the oxygen for burning the coal, so the muscle needs oxygen, which is brought to it by the blood. The blood gets it from the air in the lungs, and the lungs are as necessary as anything else for muscular movement. They are needed, not only to supply oxygen, but to carry off the waste products of combustion; for just as a fire produces smoke and gases which must be carried off up the chimney or they will put out the fire, so the muscles when active produce carbon dioxide, which is taken up by the blood and carried to the lungs, and there passed out into the air. Like an engine, again, the muscles cannot act without pro-

ducing a great deal of heat; if this were not passed out of the body, we should be consumed with fever during muscular activity. The heat goes off largely through the skin, and especially by the evaporation of sweat. The skin and sweat glands thus do an essential part of the work.

When a man runs, his breathing becomes rapid, supplying his blood with plenty of oxygen, and removing the gaseous wastes rapidly from it. The heart beats fast, and the blood flows rapidly through the muscles of his legs. Sweat breaks out on his skin, and evaporates, removing the surplus heat which the muscles are producing. His brain and sense organs are active in directing his course. Still other organs come into play, especially the liver, which gives up its stores of food to the blood, to be carried to the muscles which need it. In a long hard race, a runner may lose as much as ten pounds of weight. Some of this comes from the muscles, and some from the liver; much of it is water from the blood and the tissues generally, which has been poured out on the skin. Vigorous muscular exercise exercises nearly every organ of the body, except the digestive organs, which, however, get into action afterwards, since

the loss of substance stimulates the appetite.

As muscle work involves brain work, so brain work involves muscular work. We either write our thoughts, or speak them, or at least express them by the movements of our faces. All the organs mentioned above as necessary for muscular work are needed also in brain work. Brain work does not indeed stimulate the muscles, lungs and heart to great activity, and does not give the body generally enough exercise to keep it in good condition. At the same time, a reasonable amount of mental activity is better for health than a stagnant brain.

While the work of the internal organs is largely beyond intelligent control, except so far as concerns the diet, the work of the muscles, the brain and the sense organs is directly subject to control. We can, to a large degree, regulate the quantity of work, and the sort of work, in accordance with the demands of health. In the following chapters some account will be given of the muscles, sense organs and nervous system, and some suggestions will be made regarding the healthy use of these organs.

CHAPTER XI

THE MUSCLES

So important are the muscles to the sort of life to which man, like other animals, is primarily adapted, that the sum of the muscular tissue in the body is a large share of the total weight. There are several hundred muscles, varying in size from the large muscle that forms the front of the thigh and straightens the knee to the almost microscopic muscles that move the tiny bones of the middle ear. They vary also in shape, some being long and slender, others short and thick, others thin and sheetlike and yet others circular or ring-like. Most muscles are attached to bones, either directly or by means of cords or tendons; but a few are attached to other stiff structures, such as the eyeball or larynx, while the circular muscles, like that which surrounds the mouth and purses the lips, need no attachment whatever. Usually, a muscle is attached to two bones, and its action is exerted on these bones. According to the way in which it is attached to the bones, it may cause any

one of several sorts of movement. It may bend or "flex" the joint between them, as the biceps flexes the elbow; or it may extend the joint, as the triceps does; or it may rotate one bone on another, as certain muscles of the forearm turn the hand palm up or back up. Muscles are found in antagonistic pairs, one to flex and the other to extend a joint, etc., for whatever movement is made must be unmade again. When one of two antagonistic muscles contracts or shortens and pulls, the other relaxes, so that neither impedes the action of the other. This harmonious action of different muscles is brought about by the nerve centers that control them. The muscles act, as a rule, not singly but in groups, and their grouping, again, is brought about by the nerve centers. The nerve centers are said to "coördinate" the action of the muscles.

Under the microscope, the muscle is found to be made up of many slender fibers running lengthwise, surrounded by tough sheaths of "connective tissue," but internally soft and even semifluid, like other living cells. The inside of the fiber is composed of cross-bands of two sorts of substance, and these bands are part of the inner mechanism by which the muscle works. When it acts, one set of cross-bands suck up the

fluid from the other or alternate set, and this causes the fiber to become fatter and shorter. Since all the fibers in a muscle act in this way at the same time, the whole muscle grows fatter and shorter, and exerts a pull, through its sheaths of connective tissue, on the tendons and finally on the bones to which they are attached.

Chemically, the muscle fiber, like all other forms of living matter, is made up essentially of protein, salts and water. It also contains a store of carbohydrates, which it burns up rapidly when it acts. It stores up oxygen, too, so that it is not absolutely dependent on the blood, but can act for a short time even if its blood supply is cut off. This ready stock of fuel and oxygen enable it, when an emergency calls for extreme effort, to develop great power for a short time. When the muscle contracts, chemical action takes place in it, much like that which occurs in a furnace, when the coal unites with oxygen. Carbon dioxide, and other wastes, produced by the active muscle, tend to poison the muscle temporarily, and cause the condition of fatigue.

The active muscle, like all other engines, produces heat, which indicates a waste of energy, since not all the energy of the fuel goes to do the work for which the engine is designed. The

muscle is much more efficient than the steam engine, which loses in heat 85-90 per cent of the fuel energy, while the muscle probably wastes 50-75 per cent. In mild activity, the heat produced by the muscle is not entirely wasted, since it serves to keep up the body temperature. But when the muscle is acting strongly, the heat is distinctly a waste, and has to be gotten out of the body as rapidly as possible.

Muscular strength is partly a matter of the size of the muscles, and exercise increases strength partly by increasing the size. But this is not all, for it is a curious fact that training sometimes increases the strength without adding perceptibly to the size of the muscles, and the increase in strength is always much greater than the increase in size. The muscle gains not only in bulk, but in its internal condition. Besides, the gain in strength with training does not wholly take place in the muscle, for there is an improvement in skill or "knack," which is not an affair of the muscles. The man who can lift a heavy weight, or run a fast race, not only has good muscles, but knows how to use them for accomplishing a particular result. This skill or knack is in the nerve centers, particularly in the brain. A feat of strength is also a feat of skill, and the brain

has to learn, by practice, how best to do it.

The brain comes into play in still another way, for the force of muscular contraction depends on the strength of the command which the brain sends down the nerve to the muscle. The strength of this command depends on how much interest a man takes in the act to be done, on how much determination he puts into it, and on the motives he has for exerting himself to the utmost. Competition is a strong motive, and therefore feats of strength or speed give the best records when they are done in competition. Mental influences may act to weaken as well as to strengthen the action of the muscles. Many a competitor in athletic contests "weakens" because of worry, or mental confusion, or a feeling of hopelessness and defeat, while confidence and a clear head enter largely into the composition of the winner. All this goes to show that you cannot deal with the muscles alone, but only in connection with the brain which controls them.

As to the care of the muscles, the principal matter to be considered is the value of exercise. It is undeniable that the human body, with its large natural muscular development, is adapted to a life of considerable muscular activity. Only in very recent times, compared with the lifetime

of the human race, has a sedentary life become possible; and few men are naturally fitted for a purely sedentary existence. Most men, if not all men, are better off for a moderate amount of muscular work or exercise.

The benefits of muscular exercise are of two sorts; there is the benefit to the muscles themselves, and the benefits to the organs throughout the body; the latter sort are the more important, but we will consider the former first.

If a man's work calls for muscular strength, his need of good muscular development is too evident for argument; we may leave him out of account, and consider the man whose work is more of a mental character. He has no need of great muscular strength, and we may as well nail at the outset the fallacy that it is of any advantage to him to have huge muscles. It is a mistake to suppose that the general health and vitality, the power to resist disease and live long and comfortably, is indicated by the size of the muscles, and that the more a man develops them, the more he builds up his vitality. The individual with immense muscles not infrequently succumbs readily to disease, and the man who strives zealously for the greatest possible muscular development is liable to injure himself in

the process. Great muscles should be left to those who come by them naturally, or whose work develops them. The rest of us should be satisfied with moderate development. Our ideal of a physical man should be Apollo rather than Hercules.

Serviceable muscles—that is a good practical ideal. The muscles that serve a man about his work are sufficiently developed by his work; and it may seem to him that the rest of his muscles are of no particular service to him, so that he need not bother about their condition. But occasions are sure to arise, in any man's life, when he will be forced out of his narrow round of activities. However quiet and sedentary his usual existence, he may have to swim for his life, or run, or lift a heavy object. Then if his muscles are weak and flabby, he will be helpless, or he will strain himself in the effort to rise to the occasion. Though a man cannot provide for all the emergencies that may arise, he should at least provide against those which are almost certain to arise. It is certain that a man will some day need to run. If his legs are weak and all out of practise in running, he is liable to injure himself. The legs should be kept in fair, serviceable condition. So also should the arms

and trunk. Remembering that success in any muscular performance depends as much on skill as on muscular training, we see that general developing gymnastics, however valuable they may be in certain respects, cannot take the place of practise in the particular forms of activity that are most likely to be serviceable. The young man should not simply secure a reasonable muscular development, but he should learn, at this time of life, how to swim, run, walk, handle heavy objects—to specify only a modest list which might well be much extended—and as he grows older, he should not allow himself to become too soft, or to get entirely out of practice in these activities. A man should be at home, not only in the specialized range of activities that belong to his business or profession, but also in the more rudimentary forms of action which belong to human life in general.

The exercises of the gymnasium and of classes in physical training cannot properly take the place of these rudimentary forms of human action, nor of exhilarating outdoor sports, yet they have value in two directions. First, they afford to many men the most convenient means of obtaining the exercise which is needed for general

health; and second, they, or some of them, are useful in securing good muscular control, good "form." They are often specially useful in setting a man up well, in giving him a good carriage. A good carriage—erect and alert, yet easy and unconstrained—is not only of great social advantage to a man, but is of hygienic value. A stooping position, with sunken head and contracted chest, is bad for the vital organs, especially for the lungs. Such a position is partly a matter of bad habit, and partly due to weak and unexercised muscles. The head drops forward, partly because a man's work calls for that position much of the time, and partly because the muscles that pull the head back and hold it erect have been allowed to grow weak. Frequent attention devoted to correcting the position may break the habit, but progress will be surer if the muscles in question receive some special exercise. A form of exercise, in which the head and shoulders are alternately thrust far forward and as far back as possible—not made too rapidly, but with a pause at each extreme position—is of value in correcting a stooping position. Many such corrective exercises have been devised, adapted each to a special defect. There is no space to detail them here, and besides they

are best learned from personal instruction by a competent physical director.

The main use of muscular exercise, for the man of sedentary life, is not so much the development of the muscles or of skill in using them, as the beneficial effects on the vital organs. We have already seen that man is adapted for a fairly active life, with considerable activity of all his vital organs. Now it is mostly the muscles that make demands on the internal organs, and stimulate them to activity. The muscles use up most of the fuel provided by digestion, and so their activity calls for good action of the organs of digestion and of the liver, and much activity of the circulation to bring the fuel to the muscles. Breathing also is stimulated by muscular exercise, because of the need of oxygen. The skin is stimulated to remove the excess heat. These organs are all dependent on the muscles to arouse them to the degree of activity which is needed for their best condition. Brain work, though it may seem real enough work to most of us, is a quiet sort of business for the heart and lungs. If a man comes into his office or study after an easy walk, and sits down to mental work, his heartbeat and breathing will slow down, showing that brain work does not call for the con-

sumption of much fuel, and does not make heavy demands on the vital orgns. It is best that, for part of the time, heavier demands should be made on these organs, to keep them in vigorous condition.

A reasonable amount of muscular exercise is beneficial in many ways, some of which are more fully discussed in other parts of this book. Exercise is useful in keeping down the accumulation of fat; for when fat accumulates, it is a sign that the individual's digestive system is capable of doing a large amount of work, and that his whole system, and particularly his muscular system, should be run at a corresponding level—or else his appetite should be held sharply in check. There should be a balance between the fuel absorbed into the body and the fuel burned by the body, such a balance being indicated by constancy of weight.

If the appetite is poor, on the other hand, and if the body is thin, exercise is a valuble stimulant to the digestive organs. If there is a tendency to constipation, exercise is of value in arousing the sluggish intestines.

To the brain, also, muscular exercise is a benefit. A clearer head, a brighter disposition, a greater force of initiative, are usually to be ex-

pected in a man who takes moderate but exhilarating exercise than in a man who attempts to spend all his time in brain work. Worry and nervousness can often be relieved by exercise, and sound sleep secured when otherwise it would be sought in vain. Out-of-door sports may furnish an outlet for abundant animal spirits, and protect a man, to some degree, from an inclination to dissipation.

Like other good things, exercise can be overdone. Beyond a moderate amount, it is of no value in promoting mental efficiency. A day, or even an afternoon, of good hard exercise leaves you too sleepy for much mental activity the same evening, and may even make you slow and stupid the next day. It is impossible to lay down a rigid rule for the time to be spent in exercise by a brain worker, or to assign the best degree of severity of the exercise; for much depends on the individual and on his convenience. The exercise should be sufficient to leave behind a distinct sensation of having been muscularly active. Though not heavy, it should be lively and exhilarating. Whether to distribute the week's time for exercise equally among the seven days, or concentrate it into a couple of solid afternoons, is also a question that does not admit of a

dogmatic answer. Probably a man should not stay in the house all day without so much as stirring out for a walk and a little fresh air; but on the other hand the whole afternoon off is specially enjoyable and exhilarating. Perhaps the best solution of this problem is to combine both plans. If the program can be so arranged as to permit a bath after exercise, and then a period of rest or relaxation before further work is attempted, the effect is extremely satisfactory. But these are minor details; good healthy exercise can be obtained without any expensive equipment, and without elaborate arrangements of any sort.

A word of caution needs to be said in regard to athletic contests, which is, that a man should know his "class," and not be ambitious to get beyond it. Some contests call for such a strain of strength or endurance as are beyond the powers of the average man even to attempt with safety. It will be recalled that the original Marathon winner, he who brought the news of the battle to Athens, collapsed and died as he reached the goal; and this has been the fate of some of his modern imitators. Such an extreme test is only for the picked few. Even the ordinary runs and games are unsafe for some persons, and sometimes for those of good muscular develop-

ment. The contests throw heavy work on the heart, and if the heart is weak, the results may be disastrous. The colleges now insist on a medical examination of candidates for the teams, and exclude those whose vital condition renders them unfit for the strain.

Another danger of competitive athletics arises from the great development which the heart, arteries and lungs receive in the course of the severe training and exercise. These organs respond to the heavy demands put on them by increasing in size. When the athlete enters his business or professional life, he brings with him the heart and lungs of an athlete. There is such a thing as having too great a development of these organs, too great, that is to say, for the work that will hereafter be put on them. If the former athlete drops all his athletics, and allows himself to become soft, his big heart may degenerate, and his big and unused lungs may be the easy prey of the tubercle bacillus. This danger can be over-stated, for it has been found that former members of the crew of one of the universities became, as a rule, men of good health. Any one, however, who goes in to be an athlete in his youth, should plan to take a good deal of active exercise throughout his later life.

CHAPTER XII

THE EAR

Sense organs in general. Less vital than such organs as the heart and lungs, the organs of sense are still needed for life; and, though a man may live in health without sight, or without hearing, or even, perhaps, without touch, it would scarcely be possible for him to remain long alive with no senses whatever. Even if only one of the important senses is lacking, the unfortunate is dependent on the good will of others, and could not survive the struggles of fierce natural competition. Since reflex action starts in every case with a stimulus to some sense organ, it would not occur in any one who lacked the function of all the senses, and such important reflexes as those of breathing and swallowing, and those of evacuation of the bowels and bladder, would not occur. The brain, also, needs to be aroused by way of the senses, so that, while the absence of even such an important sense as sight or hearing does not necessarily much diminish mental activity, and though a few individuals

are on record who have displayed great intellectual vigor though both blind and deaf, yet it is probably safe to assume that the brain would be hopelessly dormant in the absence of all the senses.

There are animals low down in the scale that have no apparent organs for sensation; but this turns out to be no exception to the rule that the senses are necessary to life, for these animals, though without special organs for the purpose, are nevertheless sensitive, and respond to what acts upon them. Even unicellular animals respond by movements to electric shocks, to certain chemical substances, to heat or cold, and to jars and contacts; many of them, also, to light and darkness. Some of them move towards the light and some towards the dark, all move away from places that are too hot or too cold for their welfare, all move towards the chemical effluvia that indicate the presence of food. Without such powers of responding to beneficial and harmful conditions around them, they could not nourish themselves nor escape injury and destruction. Sensitivity is thus a fundamental and essential property of all living cells. It is a power that is not lost when cells live together in vast organized colonies, such as the human body.

Muscle cells are sensitive to electricity and to sudden blows, and act in response to such stimuli; what is more important is that they are sensitive to the action of the nerves, by which they are usually aroused to action; and that they are sensitive to chemical influences from the blood and lymph, in such a way as to respond by taking up out of the blood the substances that they require. This last is true of all the cells of the body, for their nutrition depends on their power of responding to the presence of foods by taking them into themselves. Some degree of sensitivity is thus found in all cells.

A sense organ consists essentially of cells which are specially sensitive to some one kind of agent—those in the eye to light, those in the nose and tongue to chemical substances, those in the skin to pressure, heat or cold, those in the ear to sound. The sensitive cells of any sense organ are specially tuned to some one sort of external force, while they are insensitive to most other forces. The eye, though sensitive to a very slight force in the form of light, is not aroused by even strong forces in the shape of sound; and the ear, though so sensitive to sound, is unaffected by even a bright light. This selective sensitivity is evidently important

for any clear impressions of external objects.

The sensitive cells of the different sense organs are much alike; they are, as a rule, little slender cells, sometimes with one end prolonged into fine hairs; and it is these hairs which are sensitive, while the other end of the cell connects directly with a nerve fiber, and thus passes on the action towards the brain or other nerve centers.

Tradition speaks of five senses; but a larger number is recognized today, for the "sense of touch" was merely a rough name for a whole group of senses, including the sense for warmth, the sense for cold, the sense for painful stimuli, the sense for pressure or touch proper, the sense for the movements and strains of the muscles, and the sense for internal conditions of the body, such as are indicated by hunger, thirst, nausea, suffocation, etc. Besides, there is a sense for rotation and position of the head, the organ for which forms part of the inner ear. The exact number of senses cannot be stated, but it would not now be called less than ten or eleven.

There is little to be said regarding the care of most of the sense organs, since they are not subject to any dangers which do not also affect

the skin or other parts in which they lie. Nor is there much to be said of the care of the sense cells of the "higher senses" located in the head, though it may be mentioned that tobacco has a bad effect on the olfactory cells, impairing the sense of smell, and occasionally also causes severe injury to the cells of the sense of sight.

There is, however, plenty of scope for intelligent care of the eye and ear, since these sense organs contain much in addition to the sense cells. Accessory parts are needed to bring the light or the sound properly to the sense cells. The eye has, besides the sensitive cells of the retina, a lot of optical and motor apparatus for admitting more or less light, for focusing the light on the retina, and for turning towards any object. The mechanism is so elaborate and the care of it so important, that a separate chapter will be needed for its consideration.

The ear. The ear also, besides the sensitive cells, which are located deep in a cavity of one of the skull bones, contains much accessory apparatus, the use of which is to bring the sound waves to the sense cells. The sound-producing body, whether it be a piano string, a human mouth or a breaking dish, makes the air in contact with it to vibrate, and the vibrations, trav-

eling through the air like waves on the surface of a pond, enter the ear and strike on its drum head or "tympanic membrane." They are still, however, some distance from the sensitive cells in the cavity of the bone; and besides, these cells are immersed in lymph, a liquid composed mostly of water, and not easily set in motion by the vibrations of so light a fluid as air. The difficulty is overcome by the accessory apparatus of the ear, which, while transmitting the wave-motion from the air to the liquid, concentrates it into a very small space, and so enables it to overcome the inertia of the water.

The ear has three parts: the inner ear, that little cavity in the bone which contains the sensitive cells immersed in lymph; the outer ear, which receives the air vibrations from the outside; and, between these two, the middle ear, with its arrangements for concentrating the vibrations.

The outer ear consists, first, of the visible shell of cartilage covered with skin, which we usually dignify by the name "ear," though it does not hear and is the least important part of the organ; and, second, of a hole leading into the bone and transmitting the air vibrations. The cartilaginous shell has considerable resemblance to an ear trumpet, and probably has somewhat

the same effect, gathering air vibrations in a wide opening and concentrating them into a small space, thus intensifying them. But human beings have such absurdly small outer ears, in contrast, for example, with the fine movable specimens of a donkey, that the trumpet action is weak, and the loss of this part of the ear has very little effect on the hearing.

The hole in the head for conducting the air vibrations ends where the tympanic membrane, stretched across it, separates the outer from the middle ear. The latter is a little hollow in the bone, filled with air, and closed to the outer air by the tympanic membrane, while it communicates, on the other side, with the inner ear by two little windows, one oval and one round. These windows are closed by membranes, and on the further side of them is the liquid of the inner ear. There are three very small bones in the middle ear, one being attached to the tympanic membrane, one to the oval window, and the third lying between these two and jointed to each of them. What happens, then, is that sound vibrations in the air, entering the outer ear, strike on the tympanic membrane and set it into vibration, just as the disk of a telephone receiver is set into vibration by the sound striking on it; the

membrane moves the bones, and the bones move the oval window and so transmit the vibration to the liquid of the inner ear.

The difficulty of communicating vibrations from the air to the much heavier liquid of the inner ear is overcome by concentration and by leverage. The vibrations of the comparatively large tympanic membrane are communicated to the much smaller oval window and thus their force is concentrated. The leverage of the bones of the middle ear is such that the extent of movement is reduced in passing from the tympanic membrane to the oval window, and this helps to make it possible to set the liquid into motion. The second or round window between the middle and inner ear is necessary in order to permit the liquid in the inner to vibrate; for, since liquid is incompressible, the oval window would not be able to move inwards unless some other part of the wall of the inner ear moved outwards. The round window, opening back into the air of the middle ear, makes it possible for the oval window to move in and out and so communicate vibrations to the very small quantity of liquid in the inner ear.

The middle ear, though filled with air, is separated from the air in the external ear by the

tympanic membrane. How does the air get into the middle ear, and how is it renewed? There is a narrow tube, leading from the middle ear into the throat; it is called the Eustachian tube. By this roundabout path, air passes from the exterior, through the nose and throat, into the middle ear, or in the reverse direction. The full need for this communication is not seen till we consider that a membrane, like that of the ear drum, which has to yield readily to small forces, must be delicately balanced. It must not be stretched inwards or outwards by strong pressures, for then it will not yield to the weak pressures of the air waves. Therefore the air pressure on the inside of the drum must be the same as that in the outer atmosphere; and since the latter changes with the weather and with the elevation above sea level, there needs to be some means of frequently readjusting the pressure of air in the drum. This is accomplished by air passing in or out through the Eustachian tube. The tube is not always open, but it opens frequently. It opens during the act of swallowing, and the temporary and partial deafness which results from going down into a mine or tunnel, where the air pressure is greater than at the surface, is relieved by swal-

lowing. A cold in the head is likely to block up the Eustachian tube, and thus impair hearing for the time being.

It can readily be seen that a mechanism like the middle ear, which deals with such small things as air vibrations, needs to be delicately adjusted and flexible, and that anything that interferes with its elasticity will interfere with the transmission of sound waves through it, and so with the function of hearing. To this we will return when we come to the hygiene of the ear; but first we should cast a glance at the inner ear, the essential organ of hearing.

The inner ear is a little cavity in the bone, filled, as has been said, with lymph, and containing delicate membranous structures and still more delicate sense cells. Though it is small, it has many parts; a central rounded portion, known as the vestibule, and, opening out of this on the one side, three tubes bent in the form of a half circle and called the semi-circular canals, and on the other side a spiral tube, which, from its resemblance to a snail shell, is called the cochlea. It appears that the vestibule and semicircular canals are not concerned with hearing, but with perceiving the movements and positions of the head. The curious feelings in the head

which we experience while whirling or swinging, or starting up or down in an elevator, seem to come from these parts of the inner ear; also the dizziness which results from excessive whirling. These organs play an important part in enabling us to keep our balance automatically, and in keeping the muscles in a state of readiness for instant action. The organ of hearing is the cochlea.

A slender coiled tube, divided into three by the presence of two membranes running lengthwise inside of it, with the sense cells in the sheltered space between the membranes—that is the cochlea. These little sense cells sit in rows on one of the membranes, are connected at the bottom with the nerve fibers of the auditory nerve, and divided at the top into fine hairs which extend into the fluid with which all this space is filled. A vibration entering the inner ear by the oval window, finds its way through the liquid to the round window. On its way it gently shakes the membrane and the sense cells resting on it, and makes the hairs oscillate in the water. This motion, though so slight, is enough to arouse the hairs to life and so to start a reaction which passes to the nerve fibers and by them to the brain—and the thing is done; we hear. But

why are there such numbers of sense cells, five rows of them, with a total of fifteen thousand cells? It is likely that they are needed to give the power of distinguishing different sounds, especially tones of different pitch.

The function of the ear may be impaired, and partial or complete deafness produced, by disease of either the inner or the middle ear. If the sense cells of the inner ear are destroyed, hearing is of course absolutely destroyed. If the conducting mechanism of the middle ear becomes stiff and inflexible, it no longer conducts the sound waves perfectly to the inner ear, and partial deafness results, never as complete as when the sensory cells are gone, but often bad enough to make conversation impossible. The commonest form of progressive deafness, appearing especially in old persons, consists in a hardening of the membranes and joints in the middle ear, occurring as part of the general stiffening which goes on at that time of life. It occurs earlier in life in individuals who have an inherited tendency to this form of deafness; and it may also result from disease or injury affecting the middle ear.

More under hygienic control are the inflammations of the middle ear. Catarrh may spread

from the throat, through the Eustachian tube, to the middle ear; colds in the head may spread in the same way, and the mucous membrane lining the middle ear may "run," as the nose runs. This is apt to cause ear ache and to impair hearing for a time. If, however, the cold is quickly shaken off, no permanent injury results. A neglected cold may, however, lead to more serious conditions in the ear. The bacteria which have found their way from the throat may cause pus to accumulate in the middle ear; the pressure of this ruptures the tympanic membrane, and the pus escapes through the external ear. This condition calls for expert treatment, but, under good care, may pass away without doing much permanent harm. The hole in the membrane is repaired by new growth of the membrane. But if the inflammation of the middle ear is allowed to continue, the hole may become permanent, or the entire membrane be destroyed; or, worse still, the parts of the middle ear may become so grown together that they cannot carry sound waves with any efficiency. The inflammation may even spread to the brain and cause death. These very serious conditions probably seldom originate from a simple cold; they come oftener from the more poisonous bacteria of infectious

diseases, such as scarlet fever and influenza or "grippe." Among the minor ailments, "grippe" should be looked after with special attention as regards the ear. Good care of the mouth, nose and throat—the prevention of decayed teeth, the prompt checking of colds, the removal of adenoids and enlarged tonsils in children, the avoidance of rough treatment such as snuffing cold liquids up the nose—will lessen the chances of middle ear complications, and help preserve the hearing in its best condition. Other causes which sometimes result in middle ear trouble are blows on the head, and chilling of the body by getting the clothes drenched or by excessive bathing in cold water.

There is a chance for intelligent care of the external ear, especially of the passage or hole leading into the head. Intelligence is principally called for in the avoidance of rough treatment. Blows on the ear, or loud explosions close by, may rupture the drum membrane; even a kiss on the ear, by the suction which it exerts, has been known to rupture the membrane; and some better location should be selected. Of more importance is the matter of gentle treatment in cleaning the passage and in removing foreign bodies from it. The narrowness of this

passage protects the drum membrane at its inner end from objects which might strike against it; the passage is also curved and this has the same effect of keeping things from being thrown against the membrane. There are glands in the skin of the outer half of the passage which produce a yellowish wax. This oozes out upon the skin of the passage, and since this part of the passage slopes downwards towards the outside, the wax flows slowly to the outer end of the passage, where it can be cleaned off. The wax has an aromatic odor and bitter taste, and is disagreeable to insects, which might otherwise find the passage a good nesting-place. Thus the wax is not to be regarded as dirt, and cleaned out of the passage; it is enough to remove that which has reached the outer end and come into view. Attempts to remove it from the passage are apt to do more harm than good. For if hard scrapers are used, the skin is apt to be scratched and inflammation may result; and sometimes the hard object is accidentally pushed too far in and punctures the membrane or even injures the middle ear. Nor is the use of water and a twist of towel to clean the passage to be recommended; for the effect is apt to be the forcing of the wax back against the mem-

brane, making an "ear plug," which interferes with hearing, and has to be removed by a specialist.

Water filling the passage causes discomfort and interferes with hearing, and, if it remains there for days, may soften the membrane and do damage. A wisp of absorbent cotton should be inserted into the outer end of the passage and left there to do its work.

Foreign bodies lodging in the passage should not be allowed to stay there permanently, as they may cause irritation. But no tremendous haste is called for; and usually they should be left until the doctor can see them. Unskilful attempts to remove them usually do more harm than good. The foreign body is likely to be pushed farther back, where it may become firmly wedged in the narrowest part of the passage, or it may puncture the drum membrane and injure the middle and even the inner ear. When a person gets something into his ear, lay him down with that ear underneath, and give him some chewing gum. The movement of the jaws moves the outer part of the passage, and may work the foreign body out. If this does not succeed, do not poke in the ear with unskilled hands, but take the patient to a doctor.

While the outer and middle ear thus require some care, the inner ear gets along by itself, and there is nothing to be said of its hygiene that is not included in the general laws of healthy living. "Training of the ear," like all other training, is really, for the most part, training of the brain.

CHAPTER XIII

THE EYE

Of all the sense organs, the one which oftenest goes wrong, and yet is best understood and can be cared for most intelligently, is the eye. Some knowledge of it is of value to any one whose work requires constant and hard use of the eyes, as is commonly the case in the more sedentary and intellectual pursuits.

What we commonly see of the eye is the less essential part. From the outside appearance you would not even know that the eye was a ball, turning in a socket, though, when this fact is told you, you can readily believe it. The socket is a conical pit in the bone, not entirely filled by the eye, for there is considerable fat for padding, and there are six muscles back in the socket, attached to the bone and to the eyeball, so as to move it in all directions. Blood vessels enter the eyeball from the rear, and nerves as well—several small motor nerves which control the muscles, and one large sensory nerve, the optic nerve, which is the nerve of sight.

When we examine a person's eye from outside, we see the "white of the eye," a tough leathery cover which is packed full of the inner parts and holds everything in shape. At the very front, we see a transparent portion of the cover, the *cornea,* through which light passes into the interior. A little behind the cornea we can see the iris, or colored ring, and at its center the hole called the pupil, through which the light passes.

If we could follow the light back through the pupil we should first pass through a lens of rather tough but transparent material, and then should find ourselves in a spherical room filled with perfectly clear jelly, which simply lets the light pass through with the least possible loss. Around us is the wall of the spherical room, consisting of the tough leathery cover, lined with black to keep out all light except what comes in through the pupil. Inside of the black lining is another delicate lining composed mostly of sense cells and nerve cells; and this sensitive lining, the *retina,* is the most essential part of the whole eye.

While all the other parts of the eye are accessory apparatus, the retina, or inner lining of the eyeball, is the real organ of sight, because it is

the only part that is sensitive to the action of light. Without the retina, the eye would be absolutely blind. With the retina alone, and without the accessory parts, we should know when it was dark and when light, and by turning the head could discover the direction of the sun or of any bright light; but we could see no distinct outlines of objects; all would be a blur.

The retina owes its sensitiveness to the sense cells, of which there are two kinds, called rods and cones. The cones are fatter than the slender rods, and are functionally the more highly developed of the two. The cones are sensitive to colors as well as to light and dark; they are also able to give us clear perceptions of outline and form, while the rods are inferior in this respect as well as in color vision. The rods are, however, specially sensitive to faint light. In good light, we use the cones, but in the dim light of night we are dependent on the more sensitive rods.

The retina lines the rear half of the eyeball, and its middle portion lies directly back of the pupil. The central part of the retina has a yellowish color, and is called the yellow spot; and this is the most perfect part of the retina, being the only part that enables us to get clear

perceptions of things. At the very center of the yellow spot, there are no rods, but only cones; and cones preponderate throughout the yellow spot and adjacent region, but become scarcer and scarcer away from the yellow spot, giving place to rods. The yellow spot is the "center of clear vision," and looking at an object means aiming the eye so that the light from the object shall fall upon the yellow spot and give rise to a clear picture.

If the reader is familiar with the photographic camera, he will be interested in making a comparison between it and the eye. In fact, the eye *is* a camera, a very small one, to be sure, but fully equipped. The retina is the sensitive plate or film on which the picture is made; and it has the peculiar power of renewing itself, so that a fresh picture can be taken on it every second. The dark box, which is necessary to keep stray light from the plate, is afforded by the black lining of the wall of the eyeball. The eyelid is the shutter, and the socket corresponds to the tripod.

Like the camera, the eye has a lens; it has, in fact, two lenses, one fixed and the other adjustable for distance. On first reaching the eye, light strikes the cornea, which, with its curved,

transparent surface, causes the rays of light to converge towards a point as they pass through it. But immediately after entering the pupil, the light passes through what is called *the lens* of the eye, a small but powerful lens, convex on both sides, and thus suited to make the rays converge still more. By the combined action of the cornea and lens, the rays of light are brought to a focus upon the retina.

The eye, like the camera, has a focusing device, an arrangement by which pictures may be taken at any distance. A perfectly normal eye can get a clear view of the stars, or of an object a few inches from the eye. But it does not give clear pictures, *at the same time,* of objects which are at different distances. This can be shown by a little experiment. Close one eye, and hold before the other the point of a pencil, about a foot away and nearly in line with some object several feet away. Now you can look either at the more distant object or at the pencil point. If you look at the distant object, that appears clear and sharp, but the pencil point appears blurred; if you look at the pencil point, that is clear, and the distant object blurred. When your eye is focused for one distance, objects nearer or farther away are out of focus. If,

however, your eye is focused for an object as much as twenty feet away, it is pretty well focused for anything farther away than that, no matter how far. The near objects require the most careful focusing, and you can notice a feeling of strain in the eye, when you are looking at a very near object.

It is worth while to pause a moment to get a clear idea of what takes place in adjusting the eye for different distances. Light, we know, travels in straight lines, radiating in every direction from the luminous object. Each line of light is called a ray, and the rays of light from any bright point diverge. Since, however, all the light that enters the eye has to go through the narrow pupil, the rays that reach it from any point more than a few feet off have practically the same direction; they diverge very little and are nearly parallel. After passing through the pupil, they would make a round spot, about the size of the pupil, on the retina at the back of the eye. But they must be brought to a *point* on the retina if a clear picture of the external point is to be formed. They must, then, be made to *converge* to a point; and the convergence is accomplished by the cornea and lens, both of which are like the

convex lenses of glass which, as everyone has observed, converge rays of light and bring them to a point. But suppose that the external point from which the light comes—that is to say, the object looked at—is quite near the eye. The rays entering the pupil are then very divergent, and will make a spot on the retina larger than the pupil. They need to be converged more strongly in order to overcome their divergence and bring them to a point on the retina. Hence the lens must be made stronger, that is, more convex. And this is what happens. When the object looked at is far away, the lens of the eye is comparatively flat, but when the object is near, the lens becomes more convex. and so acts more strongly to converge the rays. This change in the shape of the lens goes on in the interior of the eye, and it required the genius of a Helmholtz to devise a means by which it could be observed; but the fact is now known with certainty. The mechanism for focusing is thus quite different in the eye and in the camera. In the camera, the lens is moved bodily forward and back, but in the eye, the lens changes its shape.

Of course the lens does not really change its own shape; there must be a muscle to do that.

There is in fact a little muscle inside the eyeball, known as the ciliary muscle; and when this muscle contracts, it causes the lens to become more convex; when the muscle relaxes, the pressure which always exists inside the eyeball flattens out the lens. The ciliary muscle is active, then, when the eye is looking at near objects, and the muscle is at rest when the eye looks at a distant object. This is why reading, or other close work, tires the eyes, and why looking at distant objects relieves them. It has been said that this tiny ciliary muscle is the hardest worked muscle in the body; not, to be sure, in man's natural state, in which he looks at distant objects more than at objects close by; but in the civilized condition, which requires that so large a part of the population shall do close work with their eyes, while even their favorite recreation is likely to be reading. One reason why outdoor exercise is restful to brain workers is that it permits the eyes to be directed to the distance, and relaxes the ciliary muscle.

We shall have more to say on this subject of eye strain, but for the present we had better return to our comparison of the eye with a camera. Both have an adjustable diaphragm at the front to regulate the amount of light admitted.

In the eye, the diaphragm is the iris, with the changeable pupil in its center. When you come out of a dark place into bright light, you are at first blinded, and cannot see distinctly till your eye grows used to the light. Meanwhile, the pupil promptly contracts, cutting out a large proportion of the light, so sparing the retina and enabling you to see better. If on the contrary you go suddenly from a light room out into the dark, at first you can see almost nothing. The pupil then enlarges to a great size, and admits as much light as possible.

But this is not the whole story of the eye's adjustment to different degrees of illumination. In photographic work, we can procure plates of different degrees of sensitiveness—very sensitive plates for short exposures or for dim light, and less sensitive plates for long exposures or for bright light. In the eye, there is but one plate, the retina, but this varies from time to time in sensitiveness. Sometimes it is "dark-adapted" or sensitive to faint light; and sometimes "light-adapted," or insensitive to faint light. When it is light-adapted, it is not blinded by bright light, but can see well in it; but when it is dark-adapted, it cannot see clearly in bright light. The eye becomes dark-adapted as a re-

sult of looking at the dark; the increase of sensitiveness begins as soon as the eye is exposed to the dark, and proceeds very rapidly for the first five minutes, and more and more slowly for half-an-hour, at the end of which time, if the eye has been steadily exposed to the dark, it is completely dark-adapted, and is thousands of times as sensitive to faint light as it was when it first came out of the bright light. Light-adaptation occurs when the eye, after being in the dark, is steadily exposed to the light; this process is more rapid than dark-adaptation. The retina not only becomes adapted to the extremes of light and dark, but to any intervening degree of brightness, so as to see most clearly at that particular illumination. It also becomes adapted to lights of different color.

These then are the points of resemblance between the eye and a camera; each has a sensitive plate or film, on which the picture is made, and, in each the plate may have various degrees of sensitiveness to light; each has a lens, a focusing mechanism, and an adjustable diaphragm. Each can also be turned in any direction; the muscles of the eyeball and of the head secure this for the eye.

Even the most perfect eye has certain minor

defects as an optical instrument, defects which the expert optician would look upon as evidences of poor design or workmanship, but these are of no practical consequence to the possessor of the eye. The perfectly normal eye is, however, the exception rather than the rule. Very often the eyeball becomes more or less deformed; it loses its perfection of shape, and the perfection of shape is essential to its use, since all the proportions have to be exactly right in order that the picture on the retina may be perfect. Deformity of the eyeball is indeed usually so slight that it cannot be seen without the aid of the oculist's instruments. But it may still be bad enough to interfere seriously with vision.

There are three common deformities of the eyeball; in the first, it is too long from front to back; in the second, it is too short from front to back; in the third, it is slightly flattened in some direction. Consider what effect each of these deformities would have on clearness of vision.

Suppose the ciliary muscle of the lens is at rest; then, in a perfect eye, light from distant objects is focused on the retina, and these objects are clearly seen with no effort of the muscle. But if the eyeball is too long from before

back, the light being focused where the retina ought to be, will be focused in front of its actual position; while if the eyeball is too short, and the retina therefore in front of where it ought to be, the light will tend to a focus behind the retina. In neither of these two cases can distant objects be clearly seen with the ciliary muscle at rest. Now if the muscle becomes active, its effect, as was said before, is to converge the rays of light more, and to bring them to a focus further forward. In the eyeball that is too long, this would do no good, for the focus is too far forward already; but in the eyeball that is too short, the action of the muscle would be to focus the light on the retina, and so to give clear vision. You can readily see, then, which of these two deformities of the eyeball would produce nearsightedness. When the eyeball is too long, distant objects cannot be seen either with the muscle at rest, nor with it active. The nearsighted eye simply cannot focus for distant objects. It has no difficulty, however, in focusing on near objects, and in fact does this with less effort of the ciliary muscle than is needed by the normal eye. The resting nearsighted eye is focused for objects at a certain number of feet, the exact distance depending on the degree of

nearsightedness, *i.e.*, on the amount of elongation of the eyeball; and this distance is the greatest at which that eye can see clearly. On the other hand, its "near point of clear vision" is closer to the eye than is the case with the perfect eye. The normal eye, by exerting its ciliary muscle to the utmost, can see clearly at a distance of four or five inches; the nearsighted eye can see at still less distance, though this is of no advantage to it, unless one is a watchmaker. There is no doubt that the nearsighted person, if his defect is pure nearsightedness, uncomplicated by astigmatism—of which more below—has a certain advantage over the normal in close work; his ciliary muscle is less hard worked. But the inability to see at a distance is a serious matter, and deprives the person of a great deal of the enjoyment of the outdoor world. The nearsighted person is usually aware of his defect, and desirous of having it corrected.

But now consider the opposite defect, which is sometimes called farsightedness; its scientific name is hypermetropia, as that of nearsightedness is myopia. When the eyeball is too short from before back, distant objects, as was said in the last paragraph, cannot be clearly seen with the ciliary muscle at rest, but can be brought to

a focus by the action of the muscle. The near point of clear vision of this eye is further off than it ought to be; instead of four inches, it may be a foot or more from the eye. This defect, at first thought, does not seem to be serious, for the hypermetropic eye can see at all distances at which the normal eye can see, except close to the eye, and the use of the eyes for such close work is usually to be avoided anyway, because it puts such strain on the ciliary muscle. But consider a moment. The strain on the hypermetropic eye is as great when the object looked at is a foot from the eye (if this happens to be the near point of the particular eye) as it is for a normal eye at the distance of five inches. It is as much strain for the hypermetropic eye to read with the book fifteen inches off as for the normal eye to read at six or seven inches, with this additional disadvantage, that the print, being further off, is the same as if it were smaller. The hypermetropic eye cannot read with comfort, unless the print is very large, at any distance. When the page is far enough off to relieve the strain on the muscle, it is too far off for reading print of the usual size. When the hypermetropic eye is fatigued with reading or other close work—and it becomes fatigued much more quickly than

the normal eye—it cannot rest itself properly by going out of doors or turning to look at the distance; for it needs to exert itself even to see the distance; it is under the same degree of strain in looking at the distance as the normal eye is in looking at objects two or three feet off. The only rest for the hypermetropic eye comes when the eyes are closed. It has to work harder for everything than the normal eye. In spite of this strain, a person with such eyes may not know that anything is wrong with them. The popular test for good eyes is to be able to see distant objects; and since the hypermetropic person can do this as well as the normal—though no better, and with greater effort—he is satisfied that his eyes are all right. He is likely to be warned by eye fatigue, or by headaches, for eye strain produces headaches, but he may not know what these mean. Thus this condition is really much more serious than nearsightedness. If one is troubled with headaches, the eyes are likely to be at fault and should be looked after.

The third deformity of the eyeball, in which it is flattened in some direction—horizontally, vertically, or obliquely—is called astigmatism. The misshapement affects the cornea, or transparent front of the eyeball. It will be remem-

bered that the cornea is in effect a lens, and has much to do with bringing the light to a focus on the retina. To do this properly, it must be a portion of a sphere, equally curved in all directions. If it is more curved in one direction than in another, clear pictures cannot be formed on the retina; for the rays from a point in the seen object, which should be brought together in a point on the retina, are brought together in a short line. A point of light, such as a star, is seen by this eye not as a point but as a streak; the star has streaks on each side of it. The streaks lie above and below the star, or to the right and left, or obliquely, according to the direction in which the cornea is flattened. Not only stars, but all objects give streaky pictures to such an eye, though the person may not be always conscious of it. Whether conscious of it or not, he does not have as good sight as he should, and is under more strain than necessary in the use of his eyes. Astigmatism is very common, and is often combined with one of the preceding defects, making them worse.

These deformities of the eyeball are common in civilized countries. They are not absent, by any means, from more primitive peoples, but undoubtedly the great amount of close work,

which civilization imposes, puts more strain on the eyes than is good for them; and this strain seems to deform the eye. It is, therefore, simple common sense for any one who has to use his eyes in close work to spare them by giving them a few moments of rest now and then, and by taking his recreation in forms that permit of relaxation of the eye. This is true, no matter how good a person's eyes may be.

But there is one good thing about these deformities; they are purely optical defects, and can be *corrected,* more or less perfectly, by optical devices, that is to say, by glasses. The hypermetropic eye can be corrected by placing a convex glass in front of the eye. Such a glass brings the light to a focus sooner, and, if of the right strength, exactly compensates for the shortness of the eyeball, and enables the eye to see distant objects without action of the ciliary muscles, and near objects with no more strain than the normal eye. In the same way, nearsightedness is corrected by concave glasses. Astigmatism is corrected by glasses which are more curved in the direction in which the cornea is less curved, and less curved where the cornea is more curved.

There are several practical points to be con-

sidered in getting and using glasses. In the first place, the two eyes of the same person are often unlike. The one may be more near-sighted, hypermetropic, or astigmatic than the other. The one may even be perfectly normal, and the other so astigmatic or nearsighted as to be of little use; and yet the person may be unaware of this. Since he uses his eyes together, he has no occasion to discover the badness of one eye. But the badness of one throws more work on the other, so that the bad one should be corrected. The eyes must be tested separately, and a glass adapted to each one. A person can test his own eyes, roughly, one eye at a time, by trying them on distant objects for nearsightedness, on objects five inches from the eye for hypermetropia, and on the stars for astigmatism. If each eye stands these tests well, and if the person experiences no headaches or tired eyes, he may be fairly sure that there is no trouble. But if there is any uncertainty, he should give his eyes the benefit of the doubt. He should not, however, try to fit himself by trying on various glasses at the opticians, nor should he ordinarily let the optician prescribe glasses for him, as opticians are altogether too ready to do. He should do the thing right,

for glasses that do not fit him perfectly may be worse than none; they may, indeed, throw additional strain on his eyes. The only course to pursue is to consult an eye specialist, or oculist, have the eyes thoroughly examined, and get glasses according to the oculist's prescription. When the new glasses are put on, the first impression may be rather unsatisfactory. Old habits in the use of the ciliary muscle have to be overcome and replaced by new ones; so that it is not strange that some time may be needed to get used to the glasses. Then again, the eyes may, and usually do change; so that the glasses which were right at first cease to give satisfaction later. A new examination is necessary. On these and other points one will have good advice, once in the hands of the oculist. There is some expense about all this, and some are inclined to think twice before embarking on it; but when we consider the importance of good eyesight, and the bad nervous effects that come from neglected eyes, we should be almost as willing to save money on a broken leg as on a deformed eye.

It is because the eye is so hard-worked that it needs care; and, as has been seen, it is the optical apparatus necessary for bringing light to

a good focus on the retina rather than the sensitive retina itself, that requires care. It will be worth while to consider a few further details regarding the way in which the eye works, in order to learn how to avoid undue strain of this important organ.

Reading may be taken as an example of hard work for the eyes. It is so principally because the eyes must be continually focused on a near object, and because of the frequent readjustments of focus that are necessary in passing along the lines of print. There are also some other facts regarding the action of the eyes in reading that it is well to know.

If you watch a person's eyes while he is reading, you will see them make a series of little jerky movements, with slight pauses between; and then one large movement in the opposite direction, followed by more little movements. If you notice carefully, you will see that the little jerky movements occur while the eye is glancing along a line of print, and that the large movement is the back swing to the beginning of another line. It is not hard to see these movements, provided you have a good view of the other person's eye, but it is of course more satisfactory to have a photograph of the eye in move-

ment, and this has been accomplished. The photographs show that the jerky movements, as well as the back swing, are actual facts. It is strange that we do not feel these movements, and that every one is inclined to think that he moves his eyes with a smooth, steady motion along the line. But experiments have shown that no one can move his eyes in this smooth, steady way, except only when he is looking at a moving object. When you mean to have your eyes glide along a page or along a wall, they really make a succession of hops or jumps. This is contrary to what we commonly believe, but you can convince yourself that it is so by watching another's eyes when he is pretending to make these gliding movements.

The jumping style of motion is useful, and the gliding form would be useless, except when a moving object is to be watched. Clear pictures can be formed of a stationary object only when the eye, too, is stationary. If the eye moved smoothly along, it would see only a blur, and no clear objects. When the eye is making one of its quick jumps, this blur is so very blurred, as well as so short-lasting, that we are usually unconscious of it. Practically nothing is seen during the jumps, and things are seen

only during the pauses or rests that come between the jumps. During each pause, the eyes are looking at some particular thing and see this thing and others near it clearly, and objects further away from this center of clear vision, more and more indistinctly.

To return to reading, we now see the use of the jerky movement. The eye pauses for an instant near the beginning of each line of print, and during this pause sees the words there; then it makes a jump to a point further on in the line, and reads what is there; then jumps to a still further point, and reads some more, and so on till the line is all seen, when it jumps back to the beginning of the next line. It takes pretty skilful work on the part of the eye to do this quickly and easily; and part of the difficulty in learning to read comes from the need of practicing the eyes in this skilled movement. When all the lines of print on a page are of the same length, the eye gets the habit of this length, and is helped in moving correctly; but when the lines are made unequal by frequent indentations, no habit can be formed, so that reading is harder on the eyes. When the lines are too long, the eye's movement is greater, and brings more strain, and besides there is more chance of los-

ing the place in passing from one line to the the next. When the lines are too near together, this last difficulty occurs again. Some ways of printing thus make much harder work for the eye than others. The length of an ordinary newspaper line is not far from right; the eye makes anywhere from three to seven stops in such a line, depending on how easy reading it is, and on the facility of the reader.

Newspaper print is, however, mostly in too small type and too closely printed to be easy for the eyes. Some books are badly printed, but few are as bad as most newspapers. Of course we cannot be fussy about our eyes; in spite of bad print, we shall have to read the newspapers—more or less. But we should bear in mind that this is about the hardest work the eyes have to do, and if our eyes give us warning, we can very well begin retrenchment by leaving out the papers, all but the headlines and well-printed parts.

It is well to know some of the other things that are hardest on the eyes, so as to be ready to cut them out whenever the eyes need rest. Reading for too long at a stretch is one of the worst things. Studying is not so bad in this respect as reading an interesting story; for when

you are studying, you are pretty sure to rest your eyes occasionally, because you get tired of the book, or else have to think something over, and so raise the eyes from the book, look at something farther off and give the ciliary muscle a rest. But an absorbing story glues your eyes to the page; you may read on for hours, never once raising them—the hardest sort of work for the eyes. It is a pity that what is a relaxation to the mind should be so tiring to its servant, the eye. If a person sits up late reading a novel, he is likely to feel fagged in the morning, largely because of his eyes. A novel-reading debauch may be nearly as bad as an alcoholic spree.

Reading in dim light is bad for the eyes; reading with the light in front is worse, for the page is darkened by contrast with the bright light, and besides the retina is overstimulated by the light shining into the eyes. The proper distance for reading is a matter of compromise between two demands. The nearer the page is to the eyes, the larger is the retinal picture of the print, but the greater is the strain on the ciliary muscle. To relieve the muscular strain, you move the page farther away, but in doing so you in effect make the print smaller. The

larger the type, the further off you can read, and this is one great advantage of large type. For the usual sizes of type, twelve to eighteen inches gives the greatest ease. When you begin a book or lesson, it is easy to select the best distance, but when the book grows exciting, or the lesson hard, you will catch yourself bringing the eyes closer and closer to the page, a natural expression of attention, like the bending forward of the spectators at a game when the play is fast. Bending forward brings them only a trifle nearer the players, and they might as well sit back comfortably in their seats, as far as seeing goes; but the instinctive tendency to get as near as possible to an interesting thing is too strong. In reading, you have to be on your guard against this tendency, and since your absorption in your reading makes you unconscious of your position, it is not easy to keep the book at the right distance. The best rule is to form a habit of looking up from the book once in a while, to give the eyes a change; then, when you start again, you can go back to the right reading distance. Reading with the head bent way over the book, or with the head thrown back, as in lying, both throw unnecessary work on the eyes. When the head is bent forward,

too much blood goes to the eyes, and produces congestion; when the head is thrown back, the eyes are forced to assume an awkward position.

In general, as has been said above, looking at distant objects, or at anything more than a few feet away, is comparatively easy and restful to the eyes. But there are some exceptions. When a thing is in lively motion, the eyes of the onlooker have to keep up a rapid succession of irregular jumps, and this becomes very fatiguing. The spectators at a game may thus find their eyes growing tired. A basket ball game is specially trying to the eyes, because the play is lively, and the spectator is comparatively near the players, and so has to keep turning his eyes through large angles. The theater is also rather severe for the eyes, especially in case of spectacular and acrobatic shows. A three-ring circus is the worst; there is so much to be seen, and you don't want to miss anything; so that you keep your eyes on a constant jump, and feel the effects later. Moving pictures also are fatiguing, and traveling by rail or trolley is much like a moving show if you look out of the window. The landscape is moving by, the foreground rapidly, the background slowly. If you watch the foreground, you have to look at a new thing every

second, and your eyes are kept on the jump. Notice the eyes of some one in the street car who is looking out of the window, and you will get an idea of the work the eyes do under these circumstances. Hence a trolley ride, or a railroad journey, is apt to tire the eyes. Looking at the distant landscape from the car window—when this is possible—is much less fatiguing. But what shall we do in the city street cars? Read? Reading the newspaper in the cars is about the hardest work of all, because the constant jarring throws the page out of focus, and calls for much additional work by the eyes. If you can't look out of the window nor read, the best you can do is to look at the advertisements or other interesting objects in the car. It is a good thing to have company at such times, if only to save the eyes.

But what are we to do with our eyes, if we are warned against reading and other close work, and against watching performances and viewing landscapes from a moving vehicle? Must we forever sit on a hill, contemplating a distant landscape, and closing the eyes when the view is brightly illuminated? The warnings given above are to be taken as cautions and not as absolute prohibitions. Certainly we shall have to

make our eyes work, and sometimes work hard. The eye is a sturdy chap; for its size, indeed, it is a regular athlete and gymnast. It is game for hard work, and stands a lot of it without complaint. But, in simple fairness and common-sense, the manager of the eye should know what work is hard for it and what easy; and when he gives the team a rest, he should not make the eye work overtime to entertain the other members.

CHAPTER XIV

NERVE AND BRAIN

If you had the opportunity of examining everything that is in your arm, you would find, besides the skin on the outside and the bones at the center, besides the muscles and their tendons, and besides the veins and arteries ramifying through the arm, and besides the straps and sheets of connective tissue binding everything together—you would find also white strings running the length of the arm, diminishing in thickness from the shoulder down, branching frequently into smaller and smaller threads, till the smallest branches are invisible. By aid of a magnifying glass, you would find the branch which penetrated a muscle splitting up so finely that its minute strands reached to every part of the muscle. In the same way, you would find little strands distributed to every part of the skin; you would find small threads entering the bones, and branching within them; and other threads ramifying about the joints and about the blood vessels, and in fact, quite generally

throughout the whole substance of the arm. The same is true of the legs and face and trunk, including the heart, lungs, stomach and intestines. If you traced these strings of *nerve* back away from the extremities of the limbs, you would find the small nerves combining into large nerves which finally pass through little holes into the backbone. The backbone is hollow; each vertebra has a good sized hole in the center, and the vertebrae are so fitted one on top of another that the holes come together and form a tube running the length of the backbone. This hole contains, besides protecting membranes, what looks like a great nerve, extending up and down the back, and all the nerves which have come in through the bone enter this great nerve and are lost in it. This is the *spinal cord.*

On top of the backbone sits the skull; and a hole in the bottom of the skull joins the hole in the uppermost vertebra; through this opening the spinal cord passes into the skull; it swells out considerably, receiving, from the head and face, more nerves which come in through little holes in the skull, and extends along the base of the large cavity of the skull; here it is called the *brain stem,* and as the stem of a plant bears

fruit, so the brain stem bears two great masses of nerve substance, called the *cerebellum* and the *cerebrum*. These two, with the brain stem, and with their protecting membranes, fill the skull, and are together called the brain; and the brain, the spinal cord, and the nerves which lead out from these "centers" over the whole body, all together constitute the *nervous system*.

A nerve is made up of fine fibers, long and thread-like, known as nerve fibers. Each extends in unbroken length from its outer ending in a muscle or other organ to the cord or brain. Those which come from organs near the centers, like the eye or ear, are only a few inches long, but those that come from the tips of the fingers or toes have several feet of continuous length.

In the brain and cord, there are two sorts of nerve substance, called the white and the gray matter. The white matter is made up of fibers, the same as the nerves. The gray matter, which lies in the middle of the cord and brain stem, but on the outside of the cerebrum and cerebellum, is made up of an intricate network or felting of very fine fibrils, in which are imbedded numberless, that is to say many billions of "nerve cells." A nerve cell has much resemblance to the cells out of which all the tissues of the body are made;

it contains a nucleus in the center, surrounded by soft, semi-fluid protoplasm. But the nerve cell differs from other cells, in that it is traversed by many microscopic fibrils, and also in that it has many fine branches. On the one side it gives out a perfect tree of short branches, which help to form the felting of fibrils surrounding the cells; and on the other side it sends out one long slender thread, which passes into the white matter, and becomes the essential part of one of the nerve fibers which we already know. The fibers in the nerves, as well as in the white matter of the brain and cord, originate in this way, as the outgrowth of nerve cells in the gray matter.

A nerve fiber which ends in the skin or muscles, or in any organ of the body, does so by splitting up into fine branches, which have various forms in the different organs, and are known as *nerve endings*. Those fibers that come to an end within the brain or cord also end by splitting up into a tuft of minute branches; and these tufts are always in the gray matter, never in the white. They also, as well as the minute branches which issue directly from the cells, help to form the dense felting of fibrils which surrounds the cells. In fact, the gray matter is

composed, essentially, of the cells and the minute and interwoven branches of the cells and of the fibers. Nerve fibers never end in the white matter or in the nerves; but either in some sense organ or muscle or other organ of the body, or else in the gray matter of the brain or spinal cord.

The use of the nerves and nerve centers does not appear on inspection, and the scientific men of old time hazarded many wild guesses before the truth was discovered. The nerves have no power of motion, like the muscles, nor any power of secretion, like the glands, they do not add strength to the body, as the bones and connective tissue do; and they do not, like the blood vessels, carry substances from one part of the body to another. Their arrangement resembles that of the blood vessels, except that they branch out from the brain and cord instead of from the heart. And their use is somewhat like that of the circulation. The blood vessels, by carrying substances from the various organs to the heart, and from the heart again to the various organs, provide a complete system of transportation between all parts of the body, and make it possible for a substance produced in any one part to be conveyed to any other part that needs it, or to

an excretory organ that will get rid of it. As a railroad system unifies a country, the circulation of blood unifies the body, so far as concerns the distribution of materials. But the blood vessels carry no mails, and provide no telegraphic service; it is the nerves that do that sort of work for the body. The nerves in fact resemble in many respects a telegraphic system. The nerve fibers correspond to the single wires which are the working units of the system; the nerves, which are collections or bundles of fibers, correspond to the collections of wires that run on the same poles. It would be as hard to ascertain the use of telegraph wires by simply looking at them as it is to see the use of nerves by inspection. Nothing seems to be done in them of any consequence; little currents of electricity go shooting along the wires from time to time, and somewhat similar currents shoot along the nerves, but that is all, and it seems of small importance till we trace the wires or nerves to their ends and discover that these currents carry messages from one end to the other, and that by this means an individual or organ in one part is able to act promptly, as demanded by what has happened in another part.

Telegraphic communication is a modern neces-

sity, and makes a country much more of a unit than was formerly the case. If the "wires are down" to a town, the business of that town goes on at a disadvantage. But if the nerve to a muscle is cut, as often happens in wounds and fractures, the muscle loses all its activity till the nerve is repaired by a process of nature which occupies many weeks. Nerves are not a modern invention, but have always been a necessity. The eye sees the lion, but the legs must run, and must do it promptly. The message from the eyes cannot be allowed simply to soak down through the tissues, if such a thing were possible, but must be carried speedily to the proper point. The sense organs are affected by happenings in the world around us, and the muscles are capable of moving the limbs so as to react usefully to these happenings, but unless there were some means of quick communication between the sense organs and the muscles, the useful reactions would not occur. The fundamental use of the nervous system is to provide quick communication between the sense organs and the muscles, or, more generally, between all parts of the body.

What it is that runs along a nerve, carrying messages from one part to another, has not been made out with certainty. Little waves of elec-

tricity can be observed to move along the nerve, and that is about all that has been detected. It is quite possible that the nerves are a sort of electrical apparatus. For the present, however, not knowing exactly what it is that passes along a nerve, we call it simply the *nerve impulse.* One thing we do know regarding the nerve impulse, and that is the speed of its motion along the nerve. This has been measured by physiologists, and found to be about one hundred to three hundred feet a second. Though this is very little in comparison with the speed of the telegraph, it is great enough to enable any muscle in the body to act within a small fraction of a second after any sense organ is affected.

The circulatory and nervous system are each centered, and in this respect differ from the railroads and telegraph lines of a country. Railroads traverse the country in all directions, but the blood vessels lead into or out of the heart. Nothing can be conveyed from one part of the body to another without first passing through the heart. The nerves too all lead into or out of the "nerve centers," that is to say, the spinal cord and brain. This makes it possible for all parts of the body to act in harmony, under the control of the centers.

The nerves of sense organs carry messages, or nerve impulses, inwards to the brain, and are called sensory nerves; nerves which run to muscles are motor nerves. The great nerves of the limbs go partly to the muscles, and partly to sense organs in the skin and the interior of the limb; they are therefore both sensory and motor, or mixed nerves. A mixed nerve contains both sensory and motor nerve fibers, each fiber being either one or the other and never having both functions combined. Along with the motor fibers we reckon fibers which run to the glands, and arouse chemical action in them, as well as fibers which have the remarkable power of causing not action, but relaxation, in the muscles of the heart and blood vessels.

To get an idea of the working of the nervous system in the simplest possible case, suppose that a bee stings the hand. The skin, which receives the injury, is powerless to escape from it; but there are sensory nerve fibers and endings in the immediate neighborhood; they are aroused by the sting, and telegraph, as it were, that is, carry nerve impulses, to the spinal cord; in the gray matter of the cord, these sensory fibers come into close connection with motor fibers running to the muscles of the arm; these fibers take up the mes-

sage, or nerve impulse, from the sensory fibers, and carry it to the muscles, arousing them to action, with the result that the hand is pulled away. This simplest form of nerve action, in which a sensory impulse directly arouses a motor impulse, is called a *reflex*. If this first local reaction does not succeed in getting rid of the bee, the sensory impulse, still coming in from the injured part, spreads more and more widely in the cord, by means of fibers which connect its various parts, and so arouses the other hand to brush away the bee, or even the legs to run away.

Some of the simplest reflexes are found in the eye. The eyelid winks when the eyeball is touched, or when its surface becomes the least bit dry; the pupil contracts when a bright light suddenly shines into the eye. These movements are involuntary and usually unconscious, but they are none the less dependent on the nervous system, particularly on the sensory and motor nerves of the eye and on a certain portion of the brain stem, where these sensory and motor nerves make connections with each other. Coughing, sneezing, breathing, swallowing, blushing, paling, sweating, hastening or slowing the heartbeat, and many other movements of the limbs, trunk, head, face, and internal organs, are reflexes.

Each depends on certain sensory fibers through which it is aroused, and on certain motor fibers which carry the impulse to the muscles which do the work; each depends also on its own small portion of the brain stem or cord, where these sensory and motor fibers connect with each other.

The motor fibers to the muscles of the arm come from the gray matter of the upper part of the cord, at about the height of the shoulders. The fibers to the leg muscles come from the gray matter of the lower part of the cord, at about the height of the waist. To the muscles of the trunk, the fibers emerge all along the middle of the cord; to the neck from the uppermost part of the cord, to the face from the brain stem. The arrangement of the sensory fibers is very similar to that of the motor fibers. Those from the legs enter the cord at about the level of the waist, and send branches into the gray matter there. These branches come into connection in this gray matter with the motor fibers to the leg muscles, and so a reflex center for the legs is formed. A similar reflex center for the arms is formed in the upper part of the cord, for the sensory fibers from the arms come in there and connect in the gray matter with the motor fibers to the arm muscles. In the same way, the gray

matter of the brain stem contains reflex centers for movements of the face and mouth.

Some of the most interesting reflex centers are located in the lowermost part of the brain stem, which has a special name, "the medulla." Into the medulla come the sensory nerve fibers from the throat, larynx, lungs, stomach and heart, and many of the motor fibers to these important organs issue from the same part. So it is natural that the medulla should contain the reflex centers for control of the heart and stomach, for secretion of the gastric juice, for swallowing, breathing and coughing. Along with the heart center, we find here too a center for regulating the size of the arteries and so for controlling the supply of blood to the various organs. Nothing can be more necessary for life than these reflexes, and no part of the body is more vital than the medulla. Destruction of it causes instant death, and therefore is a frequent means of inflicting capital punishment. Hanging breaks the neck, and causes some of the bones to pierce and break up the medulla. Breathing stops at once, and this is of course enough to cause death, without counting the other vital functions which also are thrown out of play. The centers for breathing and for control of the

heart and of the blood vessels are located near together, and so connected that what affects one usually affects the others as well. So, what makes us breathe fast usually makes the heart beat fast too.

It is true of all the centers in the cord and brain stem that they are connected with each other, some more closely, some less so. Fibers, extending up and down the cord, enable each part to "telegraph" to others and influence what they are doing. When pulling the hand away from the bee does not get rid of him, the centers for the other arm and for the legs are called into play. There are two kinds of effect which one center may have over another: it may make it act, or stop it from acting. Making it act is called, in physiology, excitation; stopping its action is called inhibition. Each center can excite other centers to produce some useful combination of movements. Each center can inhibit the action of centers which act contrary to it. The result is that all the muscles of the body are, at any moment, coöperating to produce the same effect, or at least are not working in opposition to each other. The fibers which connect the many reflex centers in the cord and brain stem bring them into coöperation, so that they really

form one great center. This one center remains, however, a democracy of smaller centers, organized on a competitive basis. There is no one center which is the head of all, but any of them, if it is excited strongly enough by its sensory nerve fibers, can dominate all the others, calling into requisition those that act in harmony with it, and inhibiting those that act counter to it.

The cerebrum, indeed, the part of the brain which is especially concerned in mental life, may be regarded as a dominating center, as king or general over the lower or reflex centers of the cord or brain stem. But even it does not possess absolute power. With many reflexes, such as breathing and winking, it does not ordinarily interfere; over some, such as that of the pupil of the eye, it has very little power. Over most, it is able to exert its influence, checking a cough, holding the breath, keeping the eyelids from winking, suppressing the reflex tendencies to evacuation of the bladder and rectum. But in any of these cases, if the stimulus is strong and prolonged, the reflex finally breaks away from brain control.

Looking at the brains of various animals, we find that the cerebrum varies greatly in size in the different kinds and that, in a general way,

the size of the cerebrum goes with the intelligence of the species of animal. Thus, the fishes, which show very little power of learning by experience, have almost no cerebrum; the dog and cat have much more; the monkeys have much more again; and in man, this part of the brain is so highly developed that it wholly overshadows all the other parts in size. Only a few very large animals, the whale and the elephant, have a larger mass of cerebrum than man. This organ is not, however, concerned only with pure thought; if it were not connected in some way with the rest of the body, it could exert no influence and would be of no value. As a matter of fact, the cerebrum is connected by many nerve fibers with the brain stem and cord, and through them, indirectly, with the sense organs and the muscles of the body. The cerebrum has no direct connection with these organs, and has no direct control over the body. It acts on the reflex centers of the brain stem and cord, which in turn act on the muscles and glands. Its action is sometimes to excite the lower centers to action, and sometimes to check or prevent their action. Often, also, it leaves them alone. In ordinary quiet breathing, the cerebrum does not participate; the breathing center in the medulla acts in re-

sponse to the sensory impulses which come to it. But when we voluntarily hold the breath, the cerebrum is inhibiting the medulla; and when we voluntarily breathe fast, the cerebrum is exciting the medulla to greater action. Not all of the actions of the cerebrum are voluntary; for all sorts of thoughts and emotions have influence on the rate and depth of breathing, though we have no intention of this sort. The same sorts of influence as are exerted on the breathing center from the cerebrum act also on the other reflex centers, which are sometimes excited—commanded to act—and sometimes inhibited, or commanded to cease acting. By this means, a man makes his limbs move as he wills, and by this means also his movements express his thoughts, whether he wills it or not. Both the intentional and the unintentional signs of mental life take their start from the cerebrum.

The fibers which connect the cerebrum with the lower centers enter at its base in a compact bundle, and then spread out in the white matter and pass to many parts of the gray matter, which lies on the surface. Where the fibers are all massed together, at the base, they are often exposed to injury, in old persons, by the bursting of a little artery which lies close by. This causes

a sudden stroke of apoplexy, and results in paralysis. The paralyzed person may will to move his arm, and the muscles of his arm and the centers in the cord for arm movement may be in good condition for action, yet no action occurs, because the connecting fibers are out of commission, the "wires are down," between the cerebrum which sends the message and the lower centers which should receive it.

Of the cerebral gray matter, one part, at about the center of the skull from front to back, is found to send fibers down to the brain stem and cord. This is the part which controls the movements of the body, and is called the "motor area." If it is destroyed by disease, thought has no more influence on motion, and only reflexes are left. There is another part, at the very back of the skull, which receives fibers, indirectly, from the eyes; it is called the "visual area," and disease of it causes blindness. Another part, lying within the temples, is in connection with the ears and necessary for hearing; and still other parts are connected with touch, taste and smell.

Much the greatest share of the surface of the brain—or of the gray matter—is not included in the sensory and motor areas. It is naturally supposed that the rest is devoted to the life of

thought, but, as yet, science has not been able to connect the different parts with different sorts of mental activity. Language seems to be dependent principally on the parts near the hearing area, and knowledge of objects, so as to recognize them at sight, seems to depend on the parts near the visual area; but this is only a small beginning in localization of the mental powers. The phrenologists, over a century ago, tried to map out the whole surface of the brain, and tell what each part was for—this for dealing with number, this for form, this for money-getting, this for friendship, etc., but their effort was premature and has not stood the test of time.

One thing of great importance about these higher centers of the brain is the fact that they are connected with each other by multitudes of nerve fibers. A great bundle of fibers passes between the right and the left halves or hemispheres of the cerebrum, spreading out in each half to the various parts of the gray matter. Other long fibers run between distant portions of the same hemisphere, and shorter ones connect neighboring parts. They are all alike called "association fibers," and their use is to connect the different parts. These association fibers end in the gray matter of the cerebrum, which is the

place where the connections are actually formed. They do not reach their full growth early in life, as do the fibers of the spinal cord and brain stem, but can be seen to be forming new connections in the gray matter as late as the fortieth year. The fine branches of the fibers in the gray matter can be seen, with the microscope, to increase as late as that age. The reflexes of the lower centers are inherited, but the connections formed in the gray matter of the brain are learned by experience. It is the office of the cerebrum to form new connections, *i.e.,* to learn. Whenever one learns to connect a name with a person, or several words in a poem, or combines several movements to make a skilled act, or several facts in science or business, he is making use of the association fibers in his brain.

Another interesting fact about the cerebrum, though the significance of it is not clear, is that the right hemisphere is connected with the left half of the body, and the left hemisphere with the right half. The fibers cross. The motor area of the left hemisphere controls the movements of the right arm and leg; the touch area of the left hemisphere feels what happens to the right hand; the visual area of the left hemisphere sees whatever is off to the right. The

superiority of the right hand in right-handed persons is not the result of anything in the hand itself, but is due to the greater efficiency of the left hemisphere. We are right-handed because we are left-brained. The hemisphere which is more efficient in skilled movement is also better in other things; it takes the lead in speaking, writing, reading, understanding speech, in appreciating music and recognizing objects, and perhaps in other mental work.

Though much smaller in human beings than the cerebrum, the cerebellum has yet a very respectable size, and is internally highly organized. It seems not to be connected with mental life, but to preside over the motor efficiency and balance of the body.

A healthy nervous system is necessary for bodily and mental welfare. Every one knows the bad effects of "weak nerves," "shattered nerves," "exhausted nerves." The trouble in such cases does not lie strictly in the *nerves;* it lies in the nerve centers, and mostly in the brain. It does not lie in the nerve fibers, but in the gray matter, with its cells and their delicate connecting branches. The nerves proper do not require much special care. The reader does not need to

be cautioned particularly against breaking his arm for fear he might also break the nerve and cause loss of sensation and motion, nor need he be warned against freezing or half freezing his arm, for fear of the painful inflammation of its nerves which may result, nor do we need to insist that he must not catch diphtheria or typhoid fever, for fear of the widespread inflammation of the nerves which is sometimes an after effect. Almost anything that injures the nerves does much other damage and so is known and shunned. Some few things, not usually regarded as dangerous, do, however, often cause injury to nerves. Influenza or "grippe" is often laughed at, or was when it first came around, but now it is known to have many bad after-effects, among which is, occasionally, inflammation of the nerves. Exposure to cold and damp, by sitting on damp ground, or by neglecting to remove drenched clothing, is bad in many ways, and one of them is the tendency to cause inflammation of the nerves. Sometimes severe and unaccustomed muscular work, work in strained positions, squeezes or stretches a nerve so hard as to break or bruise it. The same may happen from pressing steadily on a nerve, as by lying a long time on a part of the shoulder where a nerve is near

the surface. There is not much danger of this because sensations of discomfort make us change our position. Even a sleeper often changes his position. In drunken sleep, however, these protective changes of position are apt not to occur; and as one who is drunk often falls asleep in awkward positions and is not careful to pick out a soft bed, he sometimes wakes up with a mysterious loss of sensation in one of his arms and with a paralysis of a group of muscles. This is just one argument more against getting drunk. Many of the worst effects of alcohol are exerted on the nervous system, so that you will find no class of men more set against alcoholic excesses than the nerve doctors. Among the causes of inflammation of the nerves (or "polyneuritis"), the most common is alcoholism, especially the habitual, even though "moderate" use of strong liquors. This disease, with its pain, loss of sensations from the skin, paralysis of many muscles, and frequent loss of memory, usually lasts many months. The loss of sensation and movement is due to the loss of conducting or transmitting power in the nerves; the memory loss indicates also a disturbance of the brain.

Diseases of the brain and spinal cord are of many kinds, and their causes are often obscure.

Three causes stand out prominently: alcoholism, venereal diseases, and inherited nervous weakness. A very large share of the wrecks who end their days in the insane hospitals are brought there by syphilis, and many others are there because of alcoholism. The fight against these two causes of nervous degeneration is a very serious concern of modern civilization. The nation must prevent their increase if it is to preserve its health and sanity. The race must bring them under control if it is to maintain itself in the world. Fortunately the individual can look out for himself in these matters. He can avoid these causes of shipwreck; and avoiding them, he has, provided his nervous system is sound to start with, escaped most of the dangers of insanity and severe nervous disease. Hard work and the troubles of life will not seriously interfere with the healthy working of his brain.

Unfortunately, many persons inherit more or less of a tendency to nervous breakdown. Their brains have not the normal power of resistance to hard work and worry. They may go insane because of things that happen to them. Or, more often, they become "nervous" or neurasthenic, or perhaps hysterical. These troubles are not distinctly modern; they are not due to the

stress of civilized life, but are found among primitive races, and probably have always existed. But it is likely enough that the haste and competition of modern life, the complexity of our interests and of the demands on our time, the irritating noise of our streets, the eye strain to which we subject ourselves, and many other vexatious or over-stimulating conditions of our life, produce a greater number of nervous breakdowns than used to occur in the "good old times." Such, at any rate, seems to be the opinion of the authorities. Those who break down are seldom provided by nature with perfectly strong and stable brains; yet they may be capable of good mental work, and, in some cases, even of brilliant work, as is shown by a considerable number of great writers and artists who have suffered from nervousness. The most successful of these have found it necessary to work methodically and to limit the time spent in work.

If a person inherits a tendency to nervous breakdown, he should inform himself of that fact before taking up the full control of his life and affairs. He should find out whether there is nervousness of a pronounced sort in his immediate family, perhaps consulting his family physician in the matter. If he finds that there is

reason to believe that he would be liable to nervous breakdown, he need not be despondent over it, for he has still plenty of chance for a useful and happy life. He has simply to use his intelligence, together with good advice, in arranging matters. He should avoid the great causes of nervous breakdown. He may need to stay out of occupations which have a bad record for nervous breakdown. He needs to avoid undue strain, irregular habits and excesses of every sort, alcohol, overeating, sometimes coffee and tobacco, and in general to lead a thoroughly hygienic life. He may have to limit the amount of his work, but he should be the last to pamper himself or live in idleness, for idleness is one of the factors in producing neurasthenia.

Promptness, directness, and frankness are good mottoes in the hygiene of the brain. They are the antithesis of neurasthenia and similar nervous troubles. The trouble with nervous people often seems to be that they are not frank with themselves or with others, that they do not live in the real world, but in a world of their own imagining, that they do not deal with things as they are, or, at least, continually delay to deal with real things. It is easier to imagine yourself doing something noble or brilliant than to

rouse your energy to deal with what is now before you. One can by habit come into a bad condition in which pleasure is sought not, as it should be, in success and actual accomplishment, but in imaginary events of which one is the hero. When a man's work is of the sort that cannot be laid out for him by a master, but must be planned by himself, the direct motor reaction to present things needs to be often checked to give opportunity for consideration and rumination; but it requires good powers of mental control to do this kind of work and still keep in close touch with reality. The ruminating activity is apt to get the better of a man, so that he ruminates all the time, without ever reaching a decision and accomplishing results. When the results to be accomplished are of a mental character, like the solution of a problem or the writing of a book, they demand consideration and rumination, but many a man who might write a good book, or paint a good picture, finds it excessively difficult to get beyond the stage of preliminary planning. He has brilliant ideas for the writing of a book, but, when it comes to the actual composition, he delays and goes on ruminating. He finds it hard to pin himself down to the particular thing that must now be dealt with. Much mental in-

efficiency comes from this lack of promptness and directness in dealing with reality.

All mental activity is founded on the reaction to external facts. The type of action, at its simplest, is the reflex, starting with a sensory stimulus and terminating in a muscular movement. Reactions involving mentality still start with a sensory stimulus, and still terminate in a movement, but between these extremes is interpolated a variable amount of mental action—of consideration and rumination. To attempt to divorce the mental life from the world of external facts, and substitute imaginary conditions and imaginary reactions for real conditions and real reactions, may be a good relaxation on occasion, but will never do as a habit. A life of idleness, in which the real world is unimportant, is therefore unnatural and unhealthy for the brain. The best rule is to keep in touch with facts—on the one side to preserve an open and attentive mind to perceive facts as they are, and on the other side to seek satisfaction in results accomplished in the real world as opposed to the world of one's private imaginings.

CHAPTER XV

WORK, REST AND RECREATION

Part of our time is spent in sleep, and part in eating—so much, it seems, can be said about every individual in a state of health. Not much more can be said with certainty, for some never work and some take no recreation. For most people, the day may be divided into four unequal parts: work-time, rest-time, recreation-time and meal-time. Under rest are included, along with sleep, other periods of restful inaction. Recreation is a form of activity; and should include, if our classification is perfect, all the activity that is not covered by work. Recreation means about the same as play; and play is so far from inaction that it is often much more active, either physically or mentally, or both, than the work of the individual.

On second thought, it is seen that our classification is far from perfect; for it does not provide for a whole group of activities which cannot be rightly called either work or play, and in which some persons spend a good share of their time.

What shall we say, for instance, of the time spent in waiting for trains to come or for other things to happen—time occupied with merely waiting? It is not work, for it accomplishes nothing; it might be rest, if one could devote the time to complete relaxation; or it might be recreation, if there was something interesting about it; but too often it is a time of ennui or impatience, not beneficial in any way, but rather the contrary; we can characterize it as killed time or waste time. Sleep is not time wasted, nor is recreation; nor, to be sure, are eating and work; but what about worrying, fidgeting, dawdling, delaying, storming and sulking? They are as fatiguing as work, but accomplish nothing; they are as time-consuming as play, but have no recreative value. In a well-ordered life, waste time is reduced to a minimum, either by avoiding the occasions of it, or by utilizing them for work, rest or recreation.

There is yet another group of activities which it seems difficult to include under either work or recreation. The attentions that a young man devotes to his chosen lady are not work for him; yet he would hardly call them play nor say that he occupied his time in this way for the sake of recreation. Nor would the truly religious man say either that it was work for him to go to

church, or that he went for the sake of recreation. The lover of music does not attend a concert simply to recuperate him for his work, but because of the direct appeal that music makes to him. What a man loves, to that he devotes his time for its own sake, and not as a means to some other end. Work is done for the sake of some end to be accomplished, such as a livelihood; recreation, considered as recreation, is also a means to the ends of efficient work and general health. The things that a man does for their own sake are often the ulterior ends to which his work is devoted. The man works that he may marry the woman he loves, and that he may provide a home for his family; or he works to provide the means which will enable him to pursue the art or hobby or public interest which appeals to him. Happy is the man who loves his work itself, for then he will not need to devote most of his time to things which have no direct value for him.

The things that a man does for their own sake often have much value as recreation; but often they have little or none. Courtship may unfit a man for his work; the concert or the opera may leave the music lover fatigued, and the music may so persist in "running through his head" as to make it hard for him to apply his

thoughts to his business; even religious exercises may have a similar effect. It would certainly be narrow-minded to condemn these things for this reason, or to judge them wholly by their effects on efficiency in work. Yet it is best to know their value as recreation, to know which are good for that purpose and which are poor. Efficiency in work is so important for the majority of men, even for those who are under no financial stress, and yet have ends which they wish to accomplish, that the intelligent man should know which forms of recreation are effective and which are really no recreation at all, but perhaps the reverse. Such questions each individual must answer for himself, to a very large degree, by observing the effect on his work of each of the other activities in which he engages. Some general hints will be found scattered through this chapter, which is written from the point of view of work, and endeavors to point out some of the influences that affect working efficiency.

Fatigue is an influence which has a strong effect on work. We speak now of healthy fatigue, which arises in the course of protracted work, and which can be readily recovered from by rest. Let us look into this matter of fatigue

rather carefully, since the physiologists have furnished us with valuable information regarding it. To begin with the simplest case of fatigue, let us examine the effect on a muscle of continued activity with no opportunity for rest. To exclude the possibility that muscular fatigue may be complicated by nervous and mental fatigue, a muscle can be taken out from a freshly killed frog or other animal, and made to lift a weight repeatedly. Under such conditions, there is a gradual decline of muscular power with the progress of the work. This fatigue effect does not commence at the very start, but is preceded by an increase in power during the first few contractions. The first effect of work is to increase the activity of the muscle, and this is called the "warming-up effect"; the result of long-continued work is fatigue.

In the above simple experiment, the muscle was so much isolated from the rest of the body that it did not even have blood circulating through it. If the circulation is maintained through the muscle while it is active, the result, as you would expect, is that more work can be done. Fatigue comes on more slowly, and the warming-up period lasts longer. Now what would be the result if not only the circulation,

but the influence of the nervous system, the brain and the mind were added? The experiment can easily be tried. Let a man lift a weight, or compress a spring, once every two seconds, always making the movement in the same way so as to use the same muscles, and always doing the best he can; and let the work done by each of his efforts be recorded by suitable apparatus. The period of warming-up, followed by the progress of fatigue, is found here as well as in the isolated muscle.

Warming-up and fatigue are familiar facts of every-day experience, and the experiments simply serve to demonstrate and measure them. In athletic sports, a good opportunity is afforded to observe them both. As for the warming-up effect, the name itself is a racing term. It is customary to give a race horse a few spins up and down the track, to "warm him up." The sprinter does the same, just before his race. Ball players practise a little just before a game; and this practise is hardly for the purpose of teaching them anything new—it is rather late for that—but simply to get them warmed up to their work. The "warming-up" is not wholly, or principally, a matter of temperature, for no rise of body temperature—no fever—need occur, and the

muscles and other working parts of the body need not be any warmer than usual. The increased power of work which results from a suitable amount of preliminary exercise is partly due to the increased circulation; but, since we saw the same thing in an isolated muscle, which had no circulation, it must be partly due to something that happens inside the muscle, some improvement in the condition of the muscle due to the fact that it has just been active.

The cause of muscular fatigue is probably twofold. A muscle is like a furnace, and uses fuel. A fresh muscle contains a store of fuel ready for use; and more is constantly brought to it by the blood which circulates through it. While fresh, it has these two sources of supply; but probably it uses up the fuel stored within it rather rapidly, and is then dependent on the blood alone, which supplies fuel rapidly enough to keep the muscle going at a fair rate, but not at its maximum. Probable as this cause of fatigue is, it is not so well demonstrated as another. When fuel is consumed, products of combustion remain behind, and need to be got rid of. The circulation carries them away from the muscle, and they are eliminated from the body; but this removal takes time, and if the muscle is working hard, these

waste products accumulate in it, because the circulation does not absorb them as fast as they are produced by the activity of the muscle. Some of the waste products of muscular action are carbon dioxide, lactic acid, and acid potassium phosphate. It is easily believed that these substances act as mild poisons and so lower the action of the muscles in which they accumulate.

A neat experiment to test the truth of this poison theory was made by Mosso, who fatigued a dog by giving him a long, hard run, while another dog had been resting at home. When the tired dog came home, all ready to lie down and rest, some of his blood was taken and injected into the veins of the fresh dog, who forthwith stopped his lively play and went and curled himself in the corner, to all appearance a tired dog. The waste products from the other dog's blood had fatigued him. Later experiments, more conclusive because simpler, have been made on isolated muscles. If moderate amounts of the substances mentioned above are circulated through a fresh muscle, and the muscle is made to contract, it shows much more rapid fatigue than a fresh muscle otherwise shows. It is certain then, that fatigue is partly due to the waste products of muscular activity; it belongs to the

class of "auto-intoxications," or self-poisonings.

After vigorous and prolonged exercise, which has called into play all the large muscles of the body and produced a large quantity of waste substances, these accumulate, not only in the muscles which have been active, but also in the blood, because the organs of elimination are not able to get rid of them as fast as the blood receives them from the muscles. In that case, the waste products diffuse out of the blood into all the tissues and organs, and cause a general fatigued condition throughout the system. Even the brain is affected, and mental work becomes difficult; sleep, or general inactivity, is what is called for. An afternoon of very vigorous exercise does not conduce to an evening of study; and it would seem that somewhat milder exercise is the best for brain-workers.

Regarding "warming-up," the statement was made that this effect was partly due to stimulation of the circulation, and partly to something that took place within the muscle. Experiment has shown that a very small quantity of the waste products—carbon dioxide and the rest—introduced into a fresh muscle, acts as a stimulant, and causes the same effect as the beginning of activity. The course of events is then as fol-

lows: when a muscle begins to act, and consume fuel, the waste products, being at first present in small quantity, stimulate the muscle, but as they accumulate with continued activity, they have the opposite effect, and cause fatigue. It is possible that the effect of a little exercise to keep one awake when on the point of going to sleep is partly due to this stimulating effect of the small quantity of wastes thrown into the circulation and carried incidentally to the brain. It seems curious that a waste and poisonous product, like carbon dioxide, should ever be beneficial, even in small quantities. But it is not so exceptional as seems at first sight, since many poisons, in very small doses, act as stimulants.

Before passing to the subject of mental work and fatigue, we may examine the mental influences that appear in muscular work. Voluntary muscular work is less regular than the work of an isolated muscle, and shows, in its irregularities, the influence of varying mental conditions. Some mental influences act to increase the muscular work, and some to decrease it; the former may be called excitatory influences, and the latter inhibitory.

The reality of these two sorts of mental influences is easily seen in the case of a man who is

running a long race. Suppose him, for the moment, to be running "against time," or at least without any competitors in sight. Then it may happen that his mind will wander from the race, so that he goes jogging along automatically, and slackens his pace. Let something remind him that he is running a race; at once he will "take a brace," and put out more speed. Mind wandering, or distraction, is an inhibitory influence, while presence of mind, or attention to the task in hand, is a stimulating or excitatory influence.

A race against time does not usually give so good a record as a race against a competitor; this is true of horses as well as of men. The social stimulus, the desire to outdo and not to be outdone, is a strong excitatory influence. Having a fixed goal to attain, a record to beat, a clearly seen standard to attain, is also a strong stimulus. It was found by experiment that a standard set before a man, a little better than he could do when left to himself, made him surpass himself and come up to the standard. If, however, the standard was set so high as to be altogether out of his reach, it acted as an inhibitory influence, and actually decreased the amount accomplished. If the standard was set below the point which he would reach by himself, he tended to rest con-

tent with equalling the standard, and did less than when left to himself. We might almost deduce a general moral precept from this simple experiment, and say, "Don't strive for the utterly impossible, for this will tend to discourage you and pull down your achievements; on the other hand, don't work without some standard, and have the standard above your previous accomplishment. As your accomplishment improves, keep raising the standard also." This is the method of successful athletes, who are always after a new record; and it is one of the lessons which may be carried over from athletics to other lines of endeavor.

Among the inhibitory mental influences, besides inattention and lack of zeal, special mention should be made of certain sensory and emotional disturbances which often give the appearance of great fatigue, when in fact there is much power of work still left. The simplest case is that of pain. If a man has hurt his foot, so that its use is painful, he cannot run, nor even walk rapidly. What is this "cannot"? The muscles are not injured, nor the nerve centers that operate the muscles; the whole motor machinery is ready for its usual work. But the pain, acting on the nerve centers, deadens their

activity; and it is well, in the interests of the injured foot, that this is so. If a very strong incentive to run occurs, the man will run in spite of the pain, which indeed may not be felt in such circumstances.

Muscular work, long continued, is itself a source of pain—either local pain in the limbs and muscles used, or a more general and diffuse "feeling of fatigue." What we mean, in ordinary life, by fatigue and "being tired" is rather this feeling of fatigue than a true worked-out condition in which the muscles and nerve centers are incapable of activity. We usually stop before we reach the point of true fatigue. It is well, in a general way, that we do so, since we thus stop before excess of work does injury. It is, however, possible to go on, by virtue of strong determination or of pressing need; and the result is usually that, though it seemed that we could not do any more, we do more, and may even lose the feeling of fatigue and do much more before it returns. A certain person, after cheerfully riding his bicycle to a considerable distance from home, suddenly felt overpowered with fatigue and did not believe that he could ever ride back; but as there was no other convenient way to return, he resolved to make the

attempt, and in a few miles was riding on cheerfully again, having forgotten his fatigue. Another individual had a similar experience while out walking; he felt unable to walk much further, but instead of sitting down or crawling along at a snail's pace, he put on all steam, and in a few minutes was walking briskly and easily.

"Second wind" is a striking example of this sort of recovery from fatigue while working, but it is physiologically a rather special case. A man starts to run, and so uses up oxygen and produces carbon dioxide faster than his heart and lungs are supplying the one and removing the other. The circulation and respiration immediately respond by hastening their action, but they do not catch up at once to the increased demands, and after a time the runner is out of breath. He feels as if he were stifling and as if he might die if he kept on running. If he does keep on, his respiration and circulation catch up to his muscular activity, and he gets his second wind.

Probably some persons do not know the meaning of "second wind," because they have never kept on when out of breath. It is likely, too, that many do not know what it is to keep on working in spite of strong feelings of fatigue

and then to find the fatigue disappearing, and much further work accomplished. There is some danger in neglecting the feelings of fatigue. In bicycle riding, for instance, it is easy to overdo, because the exhilaration of rapid motion makes it easy to suppress the warning of fatigue. Some persons are prone to neglect such warnings and habitually overdo, with bad after-effects in the way of exhaustion. Others, on the contrary, are over-sensitive to feelings of fatigue, and give up at once on their first appearance. It does not appear that any injury is done by neglecting these feelings to some extent. A good test is found in the after effects; if one recovers promptly and is all right the next day, it was right to disregard the warning feelings; but muscular soreness or general lassitude, persisting after a good sleep, indicate that the normal limit was passed. If a man is in good training, he can venture much farther than otherwise. Some individuals are so much accustomed to looking for the first signs of fatigue, and taking them very seriously when they appear, that they become quite neurasthenic in regard to physical exercise; and they may become neurasthenic in regard to mental work as well if they always stop as soon as they are the least bit tired. They

grow tired sooner and sooner, till finally nothing whatever can be accomplished.

Brain work differs from muscular work in that no great quantity of fuel is consumed, and no great quantity of waste substances produced. For this reason the circulation and respiration are not much hastened, and fatigue comes on quite slowly. Experiments to determine the work curve of the brain have been carried out in the same general way as those already described on the work of muscles. Mental work of a certain sort, such as memorizing or adding, is kept up without interruption, and the speed and accuracy are measured. These experiments show for brain work the warming-up effect, the fatigue effect, and the various excitatory and inhibitory influences which are mentioned under muscular work. But the fatigue effect is rather slight and slow in appearing. The brain is probably less easily fatigued than the muscles.

Brain work seldom occurs without accompanying labor of muscles and sense organs. Strained positions of the head and neck, and also of the legs and trunk, are apt to be present during mental work, and fatigue may be felt in these parts. Of more importance is the fatigue of the eye muscles, and congestion of the eyeball, which

are apt to occur because most brain work is also eye work. Besides this, brain work is irksome for many people, who dislike to sit still and check their natural impulses to motor activity. The brain worker is liable to ennui and mind wandering, and to impulses to get up and do something with his muscles. These feelings correspond to the diffuse feeling of fatigue in muscular work, and may lead one to believe that his brain is too tired to continue longer. This feeling, like the feeling of fatigue in muscular work, may be yielded to more than is necessary, with the result that one becomes incapable of sustained mental work. Others, on the other hand, are too much inclined to disregard these impulses to stop mental work, and may take too little exercise and sleep. The fatigue that the brain worker needs most to watch for and heed is fatigue of the eyes.

Fatigue calls for rest. Taking rest is an art which many individuals have lost since their infancy. Aside from sleep, of which more anon, every one should know how to take short periods of rest during the day, as may be required. The great essential is to secure complete relaxation. To try and combine with rest some sort of activ-

ity, like reading, is to spoil the perfection of the rest. The best thing is to lie down flat, or, even, in case the legs are fatigued, to place the feet higher than the heart, and so favor the draining off of wastes from the leg muscles. The eyes should be closed, all the muscles relaxed, the mind also relaxed. It is not exactly easy to relax the muscles or the mind at will; in fact, it cannot be done by determination, for the stronger the determination, the more active the mind, and the more tension will be found in some of the muscles. The muscles will not relax while the mind is in a state of tension. The best mental attitude is that of enjoyment of the pleasure of relaxation. The relaxation comes more easily when there is a degree of muscular fatigue, predisposing to rest. A bath also conduces to a restful attitude; so does massage. Little siestas are quite a useful thing to those who work hard. They rest the heart, the muscles, the eyes, and freshen you up decidedly. They need not last long; in fact, if they are prolonged they make it necessary to warm up again to the rest of the day's work. Five or ten minutes may be enough, if the relaxation is complete. After vigorous muscular exercise, when the heart is beating hard, the rest should continue till the heart quiets down.

After mental work, a feeling of ease and freshness indicates that the rest has done its work. Some individuals, not having yet learned the need and value of work, spend a large part of their time in a sort of semi-siesta. Alternation of active work and complete relaxation is more healthy, as well as more efficient, than a continued halfway condition.

Sleep is the most perfect kind of rest—though it is not necessary that one should go to sleep to recover largely from fatigue. Just what sleep is, strangely enough, is not known. It seems to be above all a condition of the brain. It is not always a condition of complete inactivity of the brain; dreams attest a degree of brain action, but indicate that the action is not of a very high grade. Sensation is not altogether abolished in sleep, but it is largely absent. Aside from breathing and a few other reflexes, there is little movement, except in the somewhat abnormal sleep of the sleep-walker. Since the muscles are inactive, the heart and diaphragm have a chance to rest; both circulation and respiration become slow and feeble.

Regular habits of sleep are important. The number of hours needed depends on the individual; an adult needs less than a growing child, per-

haps because sleep is required for the growth of the tissues. Probably eight or nine hours is about right for the youth, and seven or eight for most adults. Many a man pegs along in fair health with scant sleep, when, if he added an hour to his sleep, his health and vigor and his zest for work and amusement would be much improved. Too much sleep is also a possibility, and seems to make a person stupid. Regular hours for retiring and arising are important, especially to those who have difficulty in getting to sleep. As to when within the twenty-four hours, the eight hours of sleep should be located, the only really important rule is that sleep should be put when conditions are favorable for undisturbed repose, when there is darkness and quiet, and when others are asleep around you. Those who undertake night work often find it difficult to get sufficient sleep in the day; there is too much disturbance, too much going on that is interesting; so that often the night worker becomes worn out, or has to give up. For the day worker, whether he shall sleep from nine to five, or from ten to six, or from eleven to seven, or twelve to eight, or one to nine, depends for the most part on the requirements of his work and social life. He should sleep when he can sleep most regularly and with

least interruption. If other conditions permit, there is no doubt that the period of darkness, which is also the period of least noise, is the best.

As it is not always possible to avoid some irregularity and loss of sleep, it is well to know the facts about "making up sleep." Experiments on healthy young people, keeping them awake all night and then the next day and night, showed that there was a certain rhythm to their drowsiness; they were sleepier during their ordinary hours of sleep than during the following day; but, though they were wider awake during the day, their mental activity was reduced, and the second night it was exceedingly hard to keep them awake. On then being allowed to sleep, they slept long, but not so long as would be expected. They did not make up, in number of hours, for the hours of sleep that they had lost. Their sleep was deeper than usual, and apparently did its work more rapidly. The greater the fatigue, in general, the deeper the sleep. Sometimes it becomes necessary, for one night, to cut off two or three hours of sleep; and the question comes, when the cut should be made, whether by going to bed late, or by rising early. There is something to be said on both sides. If you sit up late, you will probably sleep more

deeply than usual, and partly make up the loss; whereas if you rise early, making up the loss will be postponed to the next night. Then too, close work, such as study, in the morning before breakfast, is specially hard on the eyes. On the other hand, one may be too sleepy at night to do efficient work; or, on the contrary, one may get so wide awake from late work as not to go to sleep easily. It is hard to give a general rule, except indeed that such irregularities should be avoided whenever possible.

Insomnia is something much to be avoided, even partial insomnia, in which one lies awake for an hour or two before going to sleep. It is a bad habit to try to work or think seriously after retiring. Few can do effective thinking in this way, and the habit should be to drop everything and go to sleep as soon as one is in bed. Habit will do a great deal here as elsewhere. The insomniac worries or ruminates on and on, while lying in bed, and all to little purpose. He is not quite willing to let go of what interests him, and give himself up to the pleasure of drowsiness. Genuine muscular fatigue is often a help here, also baths, massage, etc.

One difficulty in dealing with insomnia is the dread of it. This makes a person notice whether

he is going to sleep or not, and so wakes him up. The good sleeper does not think about going to sleep, but simply goes, as a matter of course and of habit. Some persons are accustomed to read themselves to sleep, and others to talk themselves to sleep. Either practise is better than thinking in bed, but neither is as good as nothing at all.

On awakening after a good night's sleep, we might expect to be at once at our best. Fatigue is now removed, and the new fatigue, which will come with the day's work, has not yet made its appearance. Therefore the first hour of the morning would be the best. Very seldom is it, in fact, the best. Some persons need an hour or more to shake off the vestiges of sleep; others, though fully awake, find, on testing themselves, that they do not work as fast or well at once after rising as some hours later. There is a sort of inertia after rest, which has to be overcome by a process of warming-up. Children warm up more quickly than adults, and are apt to be at their best early in the day. Adults often reach their high level in the middle of the day—including the early afternoon—and some not till evening. It depends not only on the individual characteristics, but on the kind of work. Mus-

cular strength is at its best in the afternoon, which is the fitting time for athletic sports. Work calling for accuracy reaches its maximum earlier, during the morning, while work calling for little accuracy or muscular strength, but simply for quickness, is often best in the evening.

Individuals have their favorite hours for mental work, which are largely the result of habit and convenience, but partly depend on the individual makeup. Some are "morning workers" and some "evening workers," but it is impossible to divide men sharply into these two classes, for some can work well at both times, while some work best in the afternoon. Among authors, some have favored the morning hours, and some have loafed all day and worked all night. A let-up in the afternoon is very common and probably founded on nature. Still, many will find that they reach their best form after a morning's work, and, after a light lunch and a few minutes' diversion or rest, are in very good shape for a couple of hours more. If a man can arrange his own program of work, he should devote some care to finding out his individual peculiarities in this matter. If his program is set for him, he should get into regular

habits of working at the hours appointed; for habit will do a great deal here also. Probably the best habit for a business man is to plunge into his work as soon as he reaches his office; habit will make this easy, while the habit of loafing along through the morning and rushing through the work late in the day will make it very hard to work any other way. Literary men and to a large extent students, not being under daily compulsion as to their habits of work, often find it difficult to accomplish much, except when the publisher insists or the examination is at hand. Regular hours of working, and the habit of a prompt attack on the work when the hour for it arrives, are effective devices for accomplishing much with little friction. It is remarkable how much has been accomplished in this way by some able men, whose health permitted only a few hours of work a day.

While the need for rest is fairly obvious, some thought is required to discover the philosophy of recreation. As was said at the beginning of the chapter, the activities which are grouped under the head of recreation are often self-justified, because they are the expression of important parts of man's nature, which find no scope in his

regular work. But for the present we are to consider recreation as an aid to work or to health. From that point of view, why should there be anything but work and rest? If a man has wearied himself with activity, does he not require inaction, and not some other form of activity? Would it not be better if, instead of taking time for recreation, he should simply go to bed? He might be "a dull boy," but would he not do better work? There has been little scientific examination of this question, but common experience is certainly in favor of recreation.

If we are to have any real light on the matter, it seems that it must come from deep down in the physiology of the nervous system. There is one known fact that is suggestive. We know that the movements of the limbs occur in pairs of opposites, such as bending and straightening the knee or any other joint, closing and opening the fist, turning the hand palm up and palm down. Two opposite movements do not occur at the same time, since whatever arouses one inhibits the other, but it is found that a movement that has just been inhibited is specially easy to excite the next instant, and especially strong. In fact, the inhibition of a movement counts for more than rest in bringing out the full en-

ergy of the movement immediately afterwards. There is something more restful than rest, and that is the inhibition which comes with performing the antagonistic movement. Many common acts, like walking and chewing, consist of a repeated alternation of two opposite movements; each is helped by the fact that it alternates with the other.

It may be that something like this applies to brain activities; that one is inhibited by another, and that the inhibition results in a back-swing to great power. If this were true, and it is probable enough, one way of bringing about a condition of power in a much used brain function, would be to inhibit its activity—for a time not simply to stop its activity, but to do something quite different which would positively inhibit it.

When one set of muscles, as for instance those that clench the fist, is kept continuously active for a long time—not alternating with its antagonistic movement—it gets into a condition of great fatigue and stiffness; it is even hard to relax the muscles, and open the fist; this condition is called *contracture*. The best way of relieving contracture is, not perfect quiet of the hand, but strong opening of the fist by the muscles that perform that movement. This

action, antagonistic to the function which has been fatigued, is the type of recreation. In mental work, conditions analogous to contracture occur, when we keep doggedly pegging away at a baffling problem. The mind, as it were, becomes stiff over this problem—stiff and inefficient. Sometimes a distraction which occupies us with something else is followed by a fresh grasp of the problem and a solution. A simple case is the hunting in memory for an elusive name. Many have noticed that the best way to find the name was to stop looking for it and attend to something quite different; then the name may bob up of itself, or be easily found when we return to the search. There seems to be such a thing as stiffness of the mental joints, or contracture of the mental muscles, resulting from a too strained and persistent attention to one problem. The use of recreative activity is to limber up the mental joints, to relax the mental muscles by doing something quite different, thus suppressing and inhibiting, for the moment, the functions active in work, so that they may be the freer and the stronger afterward.

If this is the true philosophy of recreation, rest cannot wholly take its place. Change of activity would be necessary for the highest effi-

ciency in work. The best recreation would be some activity which afforded the most complete change from the activities and conditions of a man's work. Change of scene is valuable, change in the kind of thing or subject dealt with, and change in the sort of operation that is performed. All of these items are combined in a good vacation. One goes away from the familiar place of work, and gets into a new horizon; this alone freshens one up. One deals with a different sort of material, with fish instead of with history, with pictures and scenery instead of with contracts and torts. One performs different sorts of mental operations, observes instead of calculating, goes through motor performances instead of reasoning and memorizing. Usually, one passes from a more difficult to an easier sort of mental activity, but this need not always be the case. Some find recreation even in so intellectual a game as chess. The main thing is to get out of the ruts, to shake off the care and worry, to relieve the strain, and promote mental elasticity.

The complete change of activity that comes with the annual or semi-annual vacation is undoubtedly an extremely valuable sort of recreation, but it is not enough. To stick in a rut

seven days a week, and all the active hours of the day, for all but a small portion of the year, is to make it difficult, and in some men impossible, to take a proper vacation. Nor can a man safely leave his recreation till late in his life, after he shall have retired from business. On trying this plan, many find no mental pliability left to make a change of activity agreeable; they lapse into aimless idleness and long for the accustomed routine. In these days, when retirement at a certain age is coming to be the order of the day, and compulsory in some lines of employment, it behooves the young man, looking forward to his later life, to provide himself with some hobby, interesting enough to occupy him for a large share of his time when conditions permit. This hobby should be well selected, so as to afford genuine recreation during the period of his active working life; it should be selected largely for its recreative value.

The customs of society provide opportunity for recreation, by limiting the working hours of the day, and by omitting work from the regular program of one day in the week. These free periods give opportunity for the pursuit of a hobby and for varying activity in some way which will relieve the tension and monotony of the reg-

ular mental work. In deciding what to do on Sunday, or during the free hours of the other days, different activities should be judged largely by their "recreation value," which is measured by their influence on general health and on freshness and efficiency of work. Recreation value is dependent first of all on change of activity. But there are many other things to be taken into account. For example, alcoholic intoxication—of a mild sort, let us agree—presents certain elements of good recreation, in that it affords a change and removes worry, and makes things interesting—for instance, jokes and after-dinner speeches—which might otherwise be very wearisome; but unfortunately the chemical after-effect of the alcohol on the brain and other organs prevents the recreation from having much if any value for general health or for efficiency in work. Social functions are in many respects excellent recreation, especially as they call into play social impulses and powers which do not find much scope in work; the only trouble is that they are apt to cut short the time for sleep. Reading—interesting reading—takes the mind out of the ruts admirably, and ought to foster mental flexibility to a high degree, if it is only varied enough or at least not too unintellectual; yet reading may

be bad from the side of the eyes, when these are under severe strain during work. Fancy needle work and other artistic hobbies, music (playing from score), and many other occupations, otherwise good, may, in individual cases, be too hard on the eyes. There is much in favor of indoor games, if only they do not run away with time and cut down sleep. Spirited conversation—spirited, mind; this is a hint for the family man—is as good a recreation as could be found. A man need not be wholly self-centered in his choice of recreation, for if he devotes his energies to the entertainment of his friends, this will keep his mind active and yet give him a complete change.

Mealtime should also be recreation time; so two birds are killed with the same stone; and it is better for the digestion that the meal should be an occasion of good cheer. An unwillingness to talk makes this difficult of attainment by many men.

A good slice of the recreation time should be spent out of doors, because of the value to the system of the fresh air and the muscular exercise. Some men are contented with a walk; but if this becomes so automatic that it does not prevent the thoughts from ruminating on busi-

ness, something more stimulating is needed. Collecting—not bills, but mineral or botanical specimens, views with the camera, etc.—is just the thing for those that like it. Most men will wish to combine social diversion with their exercise, either in the form of company on their walks and rides, or in the form of some outdoor game. President Eliot once made the wise remark that the best forms of outdoor sport for young men to learn were those that they would be likely to stick to in their adult life. Too often the college athlete drops his outdoor activities when he gets out of college, because he has not the time, the opportunity, or the stimulus to keep up the sports he is used to. Moderate proficiency in a variety of sports is a better acquisition for a young man than specialization in one, because it gives him a greater store to choose from later according to circumstances. The youth is preparing himself not only for his life-work but for his life-play, and he would do well to devote some thought to this side of his education.

How to spend Sunday is a question to be decided partly in terms of recreation values, though the full question goes beyond the limits of a study of hygiene. It is not best, in the in-

terests of work, that Sunday should be devoted to work; it is better to work hard six days, in the expectation of a day of complete change, than to dilute the work, as will almost surely be done if it is spread over the whole seven. As to the comparative merits of the different religious, social, and open-air activities that are open to a man on Sunday, the best test is Monday morning. Many persons attempt too much on the first day of the week, and have to spend half of the remaining days in recovering from their recuperation. An ideal Sunday leaves you fresh and keen for work on Monday morning. There is certainly much to be said, from the purely hygienic point of view, for church attendance, if it is entered into with spirit; for where will you find a greater contrast to your usual line of activity, or so complete an absence of nervous tension, hurry, eye-strain, and other factors which leave bad after-effects?

As rest is the cure for fatigue, so recreation is the cure for worry, strain and monotony. Strain and worry cause more insanity and nervous breakdown than does hard work. They destroy the mind's resiliency by their unremitting pressure. Monotony is apt to be the portion of the willing worker; he is so comfortable at his

work that he has no desire to seek recreation; he is likely to spread his work over much time, and reduce its intensity. A short period of intense application accomplishes more than a long period of plodding. The really great worker is he who can combine intensity with endurance; but such men also have good powers of recreation. "Work while you work, and play while you play" is a good maxim, both for health and for efficiency. He who cannot quite make up his mind to cast aside his work when he goes out to play comes back without the zest and freshness which attend the rebound of a suppressed function to activity.

CHAPTER XVI

INDULGENCES

A hygienic adviser, approached by a young man who asked simply, "How shall I lead a healthy life?" would have an easy task. He could readily answer, "Choose some congenial life-work, in which you can accomplish results, and work for results; meanwhile, be mindful of the necessity of plenty of sleep and of good and varied food, and be sure to get some of the exhilaration of outdoor life and of such simple social pleasures as animated conversation with your friends, or, later, the delights of a home of your own. Also, follow certain simple rules for the avoidance of infection." This would be almost a sufficiency of advice, provided the young man possessed a healthy constitution to start with, and provided he were really contented with the best and most healthy life. But very often we wish to be told, not simply what is best for us, but how much we can stand, how far we can indulge ourselves without real danger to health. As children, we want just as much dessert as

our parents think it safe to allow us; and in youth we want to know whether it would not be safe to smoke and drink and indulge in a variety of social diversions which are apt to be exhausting no less than exhilarating.

The vogue of such things as alcoholic drinks, tea, coffee and tobacco is amazing, when one considers that they have no positive value in the promotion of health, but are purely and simply indulgences. Tobacco was introduced into the Old World at the discovery of America; but it spread so rapidly and took such hold in the East that one would suppose today that it originated there, like tea and coffee. The history of alcoholic drinks would make an interesting study. Since the production of alcohol by yeast organisms occurs in nature wherever sweet liquids such as apple or grape juice are allowed to stand for some time, it is easy to understand that the invention of fermented drinks occurred before the dawn of history and that such drinks are known to all primitive tribes. These wines, beers, etc., contain from 1 to 12 or 15 per cent of alcohol; and it is only in comparatively recent times—that is to say, during the middle ages—that the invention of the still made possible the production of whisky, brandy and other distilled liquors,

which contain up to 50 or 60 per cent of alcohol. At first, these new liquors, with their exciting taste and powerful effects, were hailed as the genuine elixir of life. They were believed to strengthen, to invigorate the mind and the body, to fortify against the rigors of the elements and the attacks of disease. It is interesting to find so canny a writer as David Hume, in the early part of the eighteenth century, explaining with all gravity that strong drink is needed in the cold Swedish winter, "to warm the frozen blood, and fortify men against the injuries of the weather"; and also in the hot summers of Italy, "in order to recruit the spirits, evaporated by heat." Wider experience, and scientific tests, have shown that alcohol does not by any means possess these fabulous powers. In polar exploration, alcoholic drinks must be absolutely excluded, for their use, so far from fortifying the body against cold, is almost sure to make it succumb to the cold. And in hot summer weather, the use of alcohol is now avoided, since it leads to discomfort and predisposes to heat prostration.

Prior to the nineteenth century, belief in the positive value of alcoholic drinks was general, and, apparently, nearly every one drank freely. But no one could avoid seeing one undesirable

consequence, namely, drunkenness, and early in the nineteenth century the crime of drunkenness became the basis of a crusade against the use of alcohol. This was, in this country at least, a religious crusade, and it led to a large share of the religious people of the country becoming total abstainers, and regarding it as nothing less than a sin to partake of wine, beer or whiskey. In fact, the community was so divided into warring camps on the alcohol question that a dispassionate examination of the facts was hardly possible. Meanwhile, however, the experience of physicians was crystallizing into rather definite views regarding alcohol, and of late scientific experiments have been employed to reach the truth. And the results have certainly been unfavorable to alcohol in the main. At least, we can say as much as this: alcohol is, at best, an indulgence, without beneficial powers (unless it be in certain diseases); and the continued use of either distilled or fermented drinks weakens the system in many respects.

Consider first what physiology has to say of the immediate effects of a moderate dose of alcohol; and, second, what the doctors have to say regarding the permanent after-effects of steady drinking.

The first effect of all is a biting sensation, along with the taste of the drink. This biting sensation is stimulating, just as a dash of cold water in the face is stimulating. This kind of stimulation continues when the alcohol reaches the stomach, and the effect is felt to be warming and bracing. Pepper would do the same. The stimulation extends to the glands of the stomach which secrete the gastric juice; and it is possible that this flow may be of benefit to individuals whose appetite is poor. On the other hand, the excessive flow may be a disadvantage, especially at any other time than just before a meal; and the alcohol in the stomach tends to retard the digestive action of the gastric juice. All this occurs before the alcohol is absorbed into the body proper; and if it never were absorbed, but this were all it did, there would be little to complain of.

But the alcohol is rapidly absorbed into the blood, and acts on several organs. It quickly causes the vessels in the skin to dilate; therefore the skin becomes red with the blood circulating through it, and a warm glow is felt. It is this warm glow which gives one the impression that alcohol is warming and a protection against cold. This appearance is fallacious; for warming the

skin is nature's way of cooling the interior. The real effect of alcohol *plus* exposure to cold is thus a loss of heat, and often the temperature of the body, in a drunken man exposed to cold, sinks far below the normal. The loss of heat due to the dilated vessels in the skin may be partly compensated for by the fact that alcohol is burned in the body, just as sugar is burned, and so gives rise to an increased heat production. Possibly this is the reason why alcoholic drinks, in hot weather, increase rather than decrease the discomfort. On the whole, experience shows that alcohol should not be used as a protection against either cold or heat, but should be taken, if at all, only when the surroundings are at a comfortable temperature.

The other principal immediate effect of alcohol is an effect on the brain, manifested by lively talk and movements, freedom from care and restraint, and a feeling of confidence and well-being. These are not, probably, purely the effects of the alcohol, since they are quite apt not to occur except when the drink has been taken in company; and experiments in which moderate doses of alcohol have been given so masked that the person receiving it did not know it was alcohol have failed often to show any effects what-

ever of the alcohol. When it is drunk in company, the mental effects are partly the result of social suggestion. The drinking is done for the sake of conviviality, and the conviviality begins to appear at the mere anticipation of the drink. The keynote of the occasion is the abandonment of self-consciousness and self-restraint; and this note might equally well be struck without the use of alcohol, if only the participants so believed. The drink, in its earlier stages, is not so much the cause of the mental state as the symbol of what is expected, like a libation to the god of conviviality.

Alcohol is usually called a stimulant, and such effects as have just been alluded to are spoken of as effects of stimulation. But it is extremely doubtful whether alcohol really stimulates the brain at all. What is certainly known regarding the action of alcohol on the brain is that it is a narcotic, or anaesthetic, similar to ether and chloroform, though slower and weaker in its action. Everyone recognizes that more than a certain small dose of alcohol is narcotic, and one prominent theory to account for the mental effects of alcohol holds that all these effects are of a narcotic character. The highest centers of the brain, this theory holds, are the first to be nar-

cotized, and then later the centers that stand somewhat lower in the scale. Now the highest centers are probably those having to do with self-control and criticism, with broad plans of life and sense for the larger value of things. The action of these centers, in many individuals at least, is to make them reserved and to keep them on their guard and on their dignity. Narcotize these centers, and the somewhat lower centers have the brakes taken off, and run apace. Gestures become animated, and talk becomes vivacious though not usually clever. This is, to be sure, only a theory; and other authorities hold that the initial effect of small doses is stimulation of the brain; it is impossible, at present, to give a scientific decision as between these two theories. But there is no doubt that all but the very temporary initial effects of alcohol are narcotic.

The value of alcohol as a stimulant for mental work has been tested by experiment, and the result has been clear that, here at least, there is no stimulation but only the opposite. Both the speed and the accuracy of mental work, or of skilled manual work, are lessened by a drink; but a characteristic effect is that the individual imagines himself to be doing better than usual, though his results show that he is doing worse.

Business men, and others who need to be clear-headed when they work, have frequently noticed this peculiar effect. Alcohol is an advantage in concluding a bargain, if you can get the other man to take the alcohol. In regard to mental work, it seems that we can make a truly scientific statement, namely, that any work that calls for clear-headedness, grasp, precision, or speed is not helped by alcohol, but hindered.

The fabled powers of alcohol turn out then, on examination, to amount to very little. Alcohol is an indulgence, and not a positive aid to health or activity. The only circumstances in which the indulgence would seem allowable are when, at the beginning of a meal, it is necessary to stimulate the conviviality of a company. Here the results certainly seem to have some value, though it should be added that equally good results are often seen in social groups that use no alcohol.

We have still to consider the after-effects of drinking. And here, the best that can be said for alcohol is that it is a lottery in which the only prizes are to get off free.

There is nothing to indicate that the continued use of alcohol is a benefit to health. It may be of use in certain illnesses, under the direction of a physician; but physicians are more chary of

prescribing it than formerly, and some go so far as to regard it valueless as a medicine. Be that as it may, we have here to consider its value for a healthy man, and here, to repeat, there is no indication that its continued use has any value. That bad results may follow is common knowledge. Even if nothing worse happens than the becoming addicted to the drink, this is bad enough. But many drinkers suffer from very pronounced injuries to their health. The liver is apt to degenerate under continued dosage, and the kidneys are apt to be weakened and fall a prey to the dreaded Bright's disease. The digestive organs also are likely to suffer. And the body's wonderful power of resisting infectious diseases is apt to be impaired so that such a disease as pneumonia finds easier victims in those who have been habitual drinkers.

But the worst of the after-effects are probably those which are exerted on the brain. Continued saturation with alcohol is pretty sure to injure the brain, and there is a loss of mental activity and efficiency. Often the trouble goes beyond this and ends in stupidity or even insanity. In fact, among the most earnest advocates of total abstinence, at the present time, are to be found those doctors who specialize in mental dis-

eases, for their experience brings home to them the frequency with which continued alcoholization results in mental disturbance. Statistics point to alcohol as one of the chief factors in the production of insanity.

It is a relief to turn from this dark picture to the comparatively trivial matter of tea and coffee. There are no superstitions in the popular mind regarding the powers of these beverages comparable to those which are commonly entertained as to the magic virtues of alcohol; and there is no degradation or ruined manhood to be mourned over in their after-effects. They are, indeed, to be reckoned among the indulgences, contributing nothing positive to health or efficiency, and desirable only from the temporary pleasure of their use. The active substance in both tea and coffee is *caffein,* a drug which is also extracted and used medicinally in its pure form, while it is, moreover, added to some of the popular soda-water syrups. Caffein has a pronounced stimulating effect on the kidneys, and also stimulates the circulatory nerve centers in the medulla, so raising the blood pressure. It also can be shown to exert a stimulating effect on some parts of the brain, resulting in increased

vivacity of movement and talking. These effects are not noticeable when the brain is fresh, but are in evidence when tea or coffee are taken in a condition of fatigue. Experiment fails, however, to show any stimulating action on the higher forms of mental activity—or any work that calls for clearness, precision or breadth and soundness of judgment. The best that can be said, in this respect, for caffein or for the drinks that contain it, is that, in ordinary doses, they do not noticeably impair brain function. The worst that can be said against these beverages is, for most people, that they tend towards a nervous restlessness and often to loss of sleep. This last may become a serious matter. Sometimes the habitual drinking of tea or coffee leads to impaired digestion or favors constipation; and many persons have found that giving up these beverages was followed by an improvement in health. Since most people drink them not for the influence of the drug they contain, but mostly for their agreeable flavor and for their warmth, it should be possible, in case of need, to find satisfactory substitutes. It should also be noted that well-made tea or coffee may preserve all the aroma while avoiding any strong decoction of the drug.

As to tobacco, few would maintain that its use is anything but an indulgence. No one has thought to discover magic powers in it, or to find it a valuable stimulant. Some users of the weed feel that they could not get along without it, and some even that they could not work without it, but they would be ready to admit that this is a matter of habit rather than of any positive effect of the tobacco. Instead of regarding it as a stimulant, most users speak of it as soothing. It would be interesting to learn what gives it its soothing properties; and the guess may be hazarded that they are due to two factors, the movements of smoking and the movement of the smoke. To see the light clouds floating in the air before one has a soothing influence. And as to the movements of smoking, of what do they remind you? Are they not, in part, very similar to that earliest of all movements, exerted by the infant on his bottle or on the "pacificator" sometimes supplied in lieu of a bottle? There is every reason why this particular movement should be soothing, and the alternate movement of blowing out the smoke is also of a gentle and quieting sort. The smoker has the advantage, in his moments of relaxation, of doing something easy and pleasing to himself. It is

much like cracking and eating nuts, or rocking in a rocking chair, or twirling one's mustache; and has the advantage of being more soothing than these other movements. More than this can scarcely be said in its favor; and it should be noted that it does not recommend itself for moments of work, when it is certainly a distraction and likely to interfere. It should be saved for moments of relaxation.

Against tobacco there is this to be said, that it contains the poison nicotine, a substance which, by paralyzing some of the regulating-nerves of the heart, causes the heart to beat faster than the body needs. When continued indulgence leads to the "tobacco heart," this is a sure indication that the time has come to stop. To train himself for such a contingency, every smoker may well follow the custom of having periods of abstinence—perhaps during Lent, or for a week at a time now and then. Ordinarily, little nicotine enters the system, otherwise the results would be much more serious. But every smoker should understand the possibility of trouble, and should keep himself in readiness to refrain from his indulgence. Smoking sometimes blunts the appetite for food, and if one's appetite needs coddling, the matter of tobacco should be looked into.

What has been said of all these substances applies to adults. In case of children and even of growing youth, the matter becomes everywhere more serious. Tobacco is often a very serious injury to them, tea and coffee are bad, and alcohol nothing less than destructive. First make sure of a well-established adult body; and then, if you will, turn your attention to the advisability of these indulgences. Those who have never used them do not miss them.

CHAPTER XVII

THE CYCLE OF LIFE

Plant a seed in the ground; it germinates and grows, absorbing nutriment from the soil and the air; it gradually unfolds the characters of its kind, and, on reaching maturity, proceeds to flower and fruit, and develops, in its fruit, seeds like the one from which it sprang. Its life is a cycle, starting from a seed and culminating again in a seed. There is such a cycle also in the life of animals, for every individual animal begins as a seed or egg, and one of the normal functions of its adult life is the production of other eggs or seeds, from which new individuals shall take their start. The smaller plants culminate so completely in their reproductive function that they die on going to seed; and this is true of many of the lower forms of animals; but in some of the higher forms, and especially in man, the parent lives to guide the infancy of the young, and thus is made possible that accumulation of knowledge and of the arts of life from generation to generation, which constitutes civilization.

Except in very primitive forms of living creature, an essential factor in reproduction is sex. The male and female elements in plants are sometimes present in the same flower, as in the lily, sometimes in different flowers on the same plant, as the tassels and silk of corn, and sometimes in different individuals, as is the case in the maple. In animals, the male and female elements are carried by different individuals; the female produces eggs and the male spermatozoa, and it is necessary that an egg and a spermatozoon unite in order that a new individual may start on its career. When we speak of eggs, we think of a hen's egg and are puzzled to know what a human egg can be like. The fact of the matter is that the hen's egg is provided by the mother with a large store of food, all enclosed, along with the egg proper, in a shell; and that the egg needs nothing but a steady warmth to enable it to utilize its store of food and develop into a young bird. The human egg, on the other hand, is retained in the womb of the mother, where it is supplied constantly with food, and where it remains till it has reached a certain stage of development.

Every human individual starts as an egg. The beginning of the individual life can be

dated from the "fertilization" of the egg, which occurs when the spermatozoon of the father reaches and unites with the egg of the mother. The spermatozoon comes from the testicle of the male, the egg from the ovary of the female, and their meeting-place is in the tube leading from the ovary to the womb. Both of them are microscopic in size; the egg, before fertilization, is a rather inert cell, while the spermatozoon has a tail and swims about till it meets with the egg. The egg is like the queen bee—there is but one of her present in the womb at a time; while the spermatozoa are like the drones or male bees—they come in a swarm, though only one actually unites with the egg. These two, the egg and the successful spermatozoon, fuse completely to form a single cell, the fertilized egg; and this egg is derived in equal measure from the father and the mother. The microscopic individual, thus originating, proceeds at once to its development. The single cell divides into two, and each of these into two, and so on, all the cells so produced remaining together as a single body. At an early stage, this body resembles a mulberry or raspberry; later, it has some vague resemblance to a worm, and later still to a fish. Only gradually does it assume a human aspect. At

first, all the cells forming the embryo are, to all appearances, alike; but differences soon appear among them. At one early stage, three layers of cells can be distinguished, and these layers maintain their separateness thereafter, the innermost layer (or *entoderm*) giving rise to the inner wall of the body, *i.e.*, to the lining of the stomach, intestines, lungs, etc.; the middle layer (or mesoderm) giving rise to the muscles, bones, heart, blood-vessels, etc.; and the outer layer (or ectoderm) giving rise to the skin, hair, sense organs, and to the brain and nerves. It is from an inbending of the ectoderm along the back, forming a groove and later closing to a tube, that the brain and spinal cord and all the nerves develop. The nervous system makes its appearance early and is always well forward in its development by comparison with the other organs; the brain is especially forward in growth. The heart and liver are also early to develop. The limbs rather lag behind, appearing first as little buds from the trunk and gradually elongating. The face also is rather slow; and, even at birth, neither the limbs nor the face has reached its final form and proportions.

Though attached to and nourished by the mother, the embryo is, from the very moment of

fertilization on, a living individual, with individual characteristics which are derived from the father as well as from the mother. The embryo feeds on the mother's blood—not that her blood passes into the embryo's mouth, nor that the blood vessels of the mother communicate directly with those of the child; but there is a surface of contact between the circulation of the child and that of the mother, where the blood of the one is separated from the blood of the other only by thin capillary walls. The arrangement is much like that, previously described, by which the blood comes into close contact with the air in the lungs. Where the child's blood vessels are thus in contact with those of the mother, oxygen and food substances are passed from mother to child, and carbon dioxide and other wastes from child to mother. At birth, the child's own breathing movements are excited, and his digestive and excretory organs quickly assume their functions.

At birth, the proportions of parts are very different from those of the adult body. The brain is one-third of its full adult size, but the muscles and bones are but a twentieth of their full size. The brain grows rapidly within the first years, and reaches practically its full size at the age of seven; while the bones and muscles mature much

more slowly. The brain is apparently fully ready for business at an early age, but its efficiency is continually increased for many years by the acquisition of new knowledge, new skill, more poise and control. The general growth of the body is rapid the first year and after that slower up to about the twelfth year, when an acceleration of growth occurs for a couple of years. This period of rapid growth occurs a year or two earlier in girls than in boys, so that girls average taller and heavier than boys from twelve to fifteen years. This period of rapid growth leads to puberty, or the beginning of sexual maturity, and it is followed by a slower growth for several years more, sometimes even as late as twenty-five. Full maturity of muscular strength and endurance is not reached till this age, and probably not for a few years more. The period of maximum muscular vigor is probably from thirty to forty, but the falling off is slight up to fifty, and need not be marked till sixty or later. Sooner or later there comes a decline, which seems, indeed, to be as inherent in the constitution of the body as its wonderful power of growth from the egg to maturity.

It is not at all surprising—when we consider the great importance to the race of the produc-

tion and rearing of children—that nature has implanted in all animals, including man, strong instincts of sex and of parenthood. The attraction of one sex for the other, and the devotion of parents—especially the mother—to the young, are fundamental facts in the economy of animal nature. Without them, the various species, and the human race, would not long survive. The object of both sexual and parental instincts is, clearly, the preservation of the race. But on the foundation of these animal instincts, human intelligence and human love of the beautiful have, by slow degrees through the lapse of ages, built up two noble superstructures which far transcend the biological foundation on which they rest. These are romance and the family. Romance is based on the sexual instinct; that is clearly true; but romance is impossible to the mere animal, for it requires intelligence and the love of beauty; and it has required, moreover, like other phases of civilization, the accumulated contributions of many generations of fine spirits to bring it to its present development. To go through life without romance is to miss one of the fairest flowers of civilization.

Family life has a double basis in nature, for it is founded on both the sexual and the parental

instincts. It combines, at its best, the flavor of romance with the most practical form of unselfish beneficence. The paternal instinct, though no doubt less keen than the maternal, will be found, once it has an object on which to exert itself, strong enough to furnish some of the fullest satisfactions of life.

Unfortunately, young men are often led to short-circuit these peculiarly human developments of the sexual instinct, and to reduce the life of sex to its lowest terms. They divorce it from intelligence and sentiment and high purpose, and make of it a mere animal activity. The harm to the individual would not be so great if it were possible to turn from this paltry state of affairs to the state in which sex is an affair of the heart; but oftentimes this change is not possible. The glamour is gone from romance and the home has lost much of its attractiveness. Much more satisfying, in the long run, is it to save oneself for the richer forms of sex life. The claim that the animal instinct is too strong to be resisted is no argument for an intelligent man to present. The supposition that health will suffer for lack of sexual activity is a pure superstition. On the contrary, the circumstances under which this lower form of sexual indulgence

must be gotten by young men make the thing unhealthy rather than healthy, and expose a man to very serious danger of infectious diseases, which may easily wreck his whole life. Something more will be said on this matter of disease in the next chapter.

Finally, a word should be said as to heredity and eugenics. It is a familiar observation that children inherit the traits of their parents, and even of their grandparents and more remote ancestors. Scientific study has verified this observation and made it more precise. Breeders, to get young animals possessing certain desirable traits, carefully select parents showing these traits; and the budding science of human eugenics proposes that the same thing can be done with man, so as to breed health, intelligence, good character and good physique, and breed out undesirable traits such as insanity and criminal tendencies. It is impossible to foresee how far nations will go in the direction of controlling the breeding of men, though it is undoubtedly true that a nation which should adopt scientific measures in this regard would gain a great advantage over other nations. But at any rate the individual can and should consider the question of eugenics in relation to his own future children.

He should especially beware of selecting a mate from any family tainted with insanity or other serious nervous weakness; and, should his own family be so affected, he should have very good advice before venturing into matrimony with the chance of perpetuating the affliction. Further, whoever can cast his mind forward to the day when his children will be his greatest pride and concern, will realize the importance of finding a partner whose qualities are not only attractive during courtship, but are such as one would like to see reappearing in the younger generation.

CHAPTER XVIII

DISEASE

Man lives in a world which is filled with almost innumerable forms of living creatures, animal and vegetable, and one of the fundamental laws of life is competition. The various forms of creature compete with each other and to a large extent prey on each other. As the wolf preys on the sheep, the hawk on the chicken, the cutworm on the garden vegetables, and the boll weevil on the cotton plant, so man himself preys on the fish and on the forest, though he has learned, to a large extent, first to provide for the growth of the animals and vegetables which he will later sacrifice for his needs. Various creatures also have a tendency to prey on man, but, by his superior intelligence, man has managed to get the better of most of his enemies, and to establish, over large regions of the earth, a condition of peace, like the famous *pax Romana,* in which man is master, and other creatures are allowed to exist only so far as they minister to his wants, or at least do not harm him. Beasts of prey are exterminated,

poisonous snakes nearly so, poisonous plants are kept within bounds, so that they can usually do no harm.

It is, however, still far from true that man has exterminated or reduced to subjection all of the enemies that prey on him. For there are in nature many sorts of creatures so minute that the unaided eye cannot discover them, and some of these love to prey on man. Man did not suspect their existence till the progress of science revealed it. He saw their work in the diseases to which he was subject, but did not know the cause of these diseases. He thought of various possible explanations of disease, such as the ill-will of gods or devils, or as the miasmas of the air, but these theories did not help him much in combating disease. He also noticed that many diseases apparently passed from one person to another, and hence called them contagious, and isolated or quarantined individuals suffering from such diseases, so combating their spread. Still, he was far from master of disease, and it remained one of the greatest causes of dread and alarm in civilized communities. When the microscope was invented, men by its use began to discover minute animals and plants of whose existence they had not dreamed. It was, how-

ever, a long time after the invention of the microscope before the practical importance of these minute plants and animals was seen. Not till the second half of the nineteenth century were the most important discoveries made which enabled man to set about intelligently to reduce these minute beasts and plants of prey to subjection.

The story of how this has come about, of how man has come to possess the knowledge necessary for the combating of the infectious diseases, is highly interesting as an illustration of the value of science, even when it seems to be concerned with matters of no practical importance. Nothing, perhaps, would seem of less practical importance than researches with the microscope into the structure and behavior of creatures much too small to be seen with the naked eye. These micro-organisms or microbes vary much in size. but one with a length of a thousandth of an inch is relatively large, while the smallest are less than a tenth of that size. For a hundred and fifty years after the microscope first revealed the existence of some of these creatures, biologists studied them with more or less success, and, especially in the first part of the nineteenth century, many facts were discovered in regard to them.

But the interest in them remained almost purely scientific. One of the problems most discussed was as to their mode of generation, whether, like the higher animals and plants, each new individual always originated from other individuals of the same kind, or whether there was a "spontaneous generation," by which they sprang into life from the action of the oxygen of the air on decaying animal or vegetable matter. They developed in solutions of decaying matter which seemed at first to contain no living thing, and the view most accepted was that they arose spontaneously in such solutions. Such a line of study, though of great scientific interest, seems certainly to be beyond the bounds of practical application.

Then came Pasteur, who, about the year 1860, was interested in the study of this question. He was able to show that, if all life in a bottle of impure water was first destroyed by boiling, and if then the bottle was completely protected against the entrance of particles from the air (though purified air was itself admitted) no living creatures developed. He thus overthrew the theory of spontaneous generation, and at the same time showed something of the means by which these minute creatures gain entrance into

a substance or "medium" in which they can grow and multiply. He further showed that such processes as the decay of dead animal and vegetable matter were due, not to the action of the air, but to the growth in them, the feeding upon them, of innumerable micro-organisms. Since the process of decay is one of the most important in nature, as without it the materials on which the higher plants live would not be restored to the soil and air, these researches showed that the microbes performed a very important part in the process of nature. Pasteur made a similar discovery regarding the process of fermentation, by which alcohol is produced. He showed that the yeast-plant, which had long been known to be necessary in some way for the success of fermentation, consumed the sugar present in grape juice, utilizing it as a food for itself, and producing alcohol as its waste product.

One of the first practical applications of these discoveries lay in the field of surgery. Previous to this time, a wound caused by accident or by the surgeon's knife had usually suppurated, and quite often the pus had spread from the wound into the blood, and caused "septic fever" or blood poisoning, a very dangerous condition. Now it was suspected that the pus was due to micro-

organisms entering the wound and multiplying there, and the English surgeon Lister found that if micro-organisms could be prevented from entering the wound, the formation of pus would be prevented, the wound would heal much more quickly, and the danger of blood poisoning be avoided. At first, it was thought necessary to have the air surrounding the patient so charged with gases poisonous to micro-organisms that they would be unable to approach the wound. But later, it was found that this source of danger was slight, and that if the surgeon's hands and instruments, the skin of the patient in the neighborhood of the place to be operated on, and all substances which were to come in contact with the flesh, were so treated as to destroy all microbes on them, the cut could be made without danger of infection. "Aseptic" surgery is surgery carried out with these precautions, and has been universally adopted, to the great advantage of all persons who need to be operated on, whether in a large or in a small way.

The work of Pasteur, and the line of thought opened up by his discoveries, led many to follow him in the study of microbes. The greatest among the successors of Pasteur has been Koch, who, in 1876, was able to show that one particular

sort of microbe was the cause of a certain disease of cattle, called "anthrax," a disease sometimes communicated to man. It was no small matter to fix the responsibility for a disease on a specific kind of microbe, for so many forms of these little creatures live together in all places where life is possible for them, and such a great variety of them can be obtained from a boil or from any diseased organ, that, though men suspected that they were concerned in the production of disease, it was very difficult to fasten the blame for any certain disease on any certain microbe. Koch was able, by great care and special devices, to isolate a certain kind of microbe from the many present in an animal afflicted with anthrax, to cause this microbe to multiply on a suitable medium, and then, by injecting some of this "pure culture" (*i. e.,* a collection of microbes all of one kind) into a healthy animal, to produce in it the disease anthrax. It was found later that it was possible to weaken the disease-producing power of such a pure culture, so that instead of giving rise to a dangerous disease, it caused only a mild attack, which, however, protected the animal from catching the disease in its dangerous form. As a result of these investigations, therefore, it is now possible to vaccinate

cattle against anthrax, and the lives of thousands of them are saved annually by this means.

Now that Koch had proved the connection between a certain microbe and a certain disease, the "germ theory of disease," according to which each of the infectious diseases is due to some special kind of germ or microbe, became prominent in men's minds and led many to follow up this line of work. Koch himself found the germ of Asiatic cholera in 1882 and that of "consumption" and other forms of tuberculosis in 1884. Other workers, both before and after this date, discovered the germs of pneumonia, spinal meningitis, diphtheria, typhoid fever, dysentery, influenza, lockjaw, leprosy, gonorrhea, syphilis, malaria, bubonic plague, and many other diseases of man, as well as the germs of many diseases of cattle, sheep, rabbits, rats, birds, fish and even vegetables. There are still a number of important diseases for which the germs have not been discovered; the list of these includes smallpox, measles, scarlet fever, yellow fever, mumps, whooping cough, and hydrophobia. Much progress has, however, been made regarding the mode of infection of these diseases. It is possible that the germs of some of them may be too small to be seen with even the most power-

ful microscopes, since some of those which have been discovered are barely large enough to be recognized with the best microscopes.

These germs, or microbes, or micro-organisms, are unicellular, that is to say, instead of being composed, like the human body, or even like the body of so small an animal as a flea, of vast numbers of cells, each is a single cell. It is hard to make sure whether they should be more properly called plants or animals, but, on the whole, the largest number of those known today are classed with the plants. These are called *bacteria,* while the smaller number of disease germs that are classed in the animal kingdom belong to the group called *protozoa.* Of the bacteria, or plant forms, there are three principal divisions, known as the cocci or balls, the bacilli or rods, and the spirilla or spirals. A coccus is a spherical cell, a bacillus is a rod-like cell, and a spirillum is a spirally twisted cell. The germs that cause the production of pus in boils and blood poisoning belong to the cocci, as do the germs of pneumonia, spinal meningitis and gonorrhea. The germs of diphtheria, typhoid, plague, influenza, lockjaw, tuberculosis and leprosy are bacilli. The germ of cholera is a spirillum, and that of syphilis is of very similar

form. The germ of malaria is a protozoan, as is that of the African "sleeping sickness."

Most of these organisms have no distinction of sex, but multiply by division; when one has grown to a large size, it divides into two, each of which is a complete individual which will, after reaching its growth, divide in its turn. In some circumstances, such divisions may occur as often as once in half an hour, so that where there is one germ now, there would be two in half an hour, four in an hour, eight in an hour and a half, and sixteen at the end of two hours. If this rate of increase were kept up for twenty-four hours, millions of bacteria would be present for every one present at the beginning of this time. This rapid rate is not kept up, but still the increase is often very rapid.

Bacteria thrive at a temperature about that of the human body; they are killed by heat, as by boiling; they are checked in their development, though not killed, by cold; freezing kills most of them. They grow best in the dark, and are killed by sunlight. Some of them require the presence of the oxygen of the air, while others can grow only in the absence of oxygen; these latter form a remarkable exception to the general rule that all living things derive the energy for

their activities from oxidation; these oxygen-hating bacteria are able to secure energy in some other way, probably by the breaking down of complex compounds in their food supply to simpler compounds.

The different varieties of bacteria require very different sorts of food. Those which produce putrefaction and fermentation live on dead animal and vegetable matter. Those that are parasitic, and concerned in the production of disease, feed on living plants or animals. There are some that live partly or wholly on inorganic matter. Some can live on ammonia and carbon dioxide, and there is one very important group of soil bacteria that are able to feed on the free nitrogen of the air, leaving it, when it has served their purpose, in a form which can be utilized by growing plants. These, and also those that live on ammonia, are of great importance to agriculture and in the general economy of nature, since they take the first step towards the building up of new protein out of the decomposition of old protein. Without them, it seems that the production of new protein by plants would cease; and as animals are dependent on plants for their supplies of protein, both vegetable and animal life are dependent on the agency of these bacteria.

Many bacteria have some power of motion, being provided with little whips by which they propel themselves through a liquid, much as a fish swims by use of his tail. Their speed of movement is respectable in comparison with their size, though it is as nothing in comparison with that of larger creatures.

It is not, however, the germ's own power of movement which enables it to pass from one person to another and so transmit a disease. The bacteria are *conveyed* from one individual to another, and the means of conveyance are different in different diseases. Let us consider the mode of transmission of the tubercle bacillus, for example. This is contained in large numbers in the sputum (spit) of consumptive patients. When this sputum is carelessly discharged, it dries into dust and is blown about. Dust, with the bacilli contained in it, easily finds an entrance into the mouth and nose of other persons, and this has at times been thought to be the principal means by which tuberculosis is spread. Fortunately, this bacillus is likely to be killed by drying and by the action of sunlight; so that actual examination of the air of city streets does not show it to be abundantly present there. It can be found, however, in the air of the sickroom

of a consumptive patient, and apparently may live in the dust of such a room for a long time, so that the room which has been inhabited by a consumptive, is, unless thoroughly disinfected, liable to infect an individual who comes to live in it after the consumptive has gone. But it is likely that the transmission of the germ from one person to another is usually rather more direct than this. When a consumptive patient coughs or sneezes, he discharges into the air little droplets of saliva and mucus, and these often contain live and active bacilli. Any person in the immediate neighborhood of the patient is likely to inhale some of these droplets, and this is probably the means by which the disease is transmitted from one person to another of a family.

Formerly, the fact that many members of the same family were likely to succumb, one after another, to consumption, was thought to indicate that the disease ran in families, and was hereditary; but now that we understand the infectious nature of the disease, we judge that it runs in families mostly because the immediate associates of a consumptive are constantly exposed to infection. There is no doubt, of course, that some constitutions are better able to resist the encroachments of the bacillus than others, and that

this power of resistance is more or less a matter of heredity.

Another manner in which tuberculosis probably spreads is from mouth to mouth, by kissing, or by the use of a common drinking cup, or by forks, spoons, etc., which may be passed from one person to another without first being cleansed and "sterilized" by the use of hot water and soap. The rims of public drinking cups are found, on examination, to harbor great numbers of bacteria, among which the tubercle bacillus is sometimes found. If we regard it as bad and disgusting manners to pass forks and spoons from mouth to mouth at the family table, we should consider whether it is not worse to drink, in a public place, from a cup which has been used by numbers of persons, clean and unclean, afflicted, some of them, with tuberculosis or other transmissible diseases. Another way in which the tubercle bacillus gains entrance to the body is, probably, with food and drink. If uncooked food has been through the hands of a tuberculous person, or if it is derived from an animal afflicted with the disease, there is the chance that the germs may be so introduced. Especially, it has been shown that the milk of tuberculous cows contains tubercle bacilli, and by many this is sup-

posed to be an important means of infection, especially of children; authorities, however, still differ widely as to the importance of this source of infection.

It may seem strange, with so many opportunities for the introduction of this germ, that all of us are not infected; and it is found, as a matter of fact, that the great majority of persons have become infected at one time or another, and bear the scars of the infection till death, when they may be discovered by post mortem examination. The scars indicate that the body has successfully resisted the disease, and after a time thrown it off. This bacillus is, in fact, one of those to which the body has strong powers of resistance. So far from being a disease of mysterious origin and necessarily fatal result, tuberculosis is now known to be preventable, and even curable if attacked before it has gone too far. The means of prevention are the avoiding of the sources of infection mentioned above, and as far as possible the isolation of the patient. The means of cure are principally a life in the open air, with good and abundant nourishment. If fresh air is a cure, it is also a means of prevention, and this adds one more argument to the many that have been mentioned in earlier chap-

ters for passing a part of every day out of doors. Since the discovery of the tubercle bacillus and the realization of the nature of the disease, the death rate from it has been cut down by a third, and it is confidently hoped that, as the people generally come to understand how to fight it, it may become a thing of the past, instead of being, as at present, one of the greatest scourges of the human race.

The typhoid bacillus passes from one person to another by quite a different route from that taken by the tubercle bacillus. Though the bacillus is present all through the body of a person sick with typhoid fever, it leaves him principally in his excretions, the urine as well as the feces. Even a minute and almost imperceptible quantity of the excretions is sufficient to pass on the infection, and consequently those who have to care for the typhoid patient are quite often infected. The rule is to disinfect thoroughly the excretions of the patient, and all clothing, etc., that has been in contact with him or his bed—to disinfect them before allowing them to leave the sickroom. When this is not done, the germs from a patient get out into the world, perhaps into the sewer, perhaps into the ground surrounding a country house. When the sewer empties

into a stream, which lower down in its course furnishes the water supply of a city, the germs are likely to get into the city water, and so to cause an epidemic of typhoid. This has happened many times in the history of different towns, and shows the need for careful attention to the condition of the water. Much can be done by sand filters at the water works, which strain out most of the bacteria contained in the water. More and more, however, it is being felt that the pollution of streams is an evil which must somehow be stopped. Even when a city secures its water from the hills, without contamination by the sewage of other towns, it sometimes happens that the excretion of a patient living in some farmhouse is not disinfected, but being simply buried in the ground is washed into the reservoir and causes an epidemic.

Other epidemics of this disease have been traced to milk. It may happen that the milk cans are washed, at the farm, in water which has been contaminated by typhoid excretions, and that in this way typhoid bacilli gain entrance to the milk. Or, it may be that some one who handles the milk has a mild attack of typhoid, which is not recognized as typhoid, and that bacilli pass from his hands to the milk. Also,

it has been found that those who have recovered from typhoid fever often continue for months, and sometimes for years, to discharge typhoid bacilli, and so, quite innocently on their part, to infect milk which they handle. It is usually easy to trace the causes of epidemics of typhoid, but much harder to understand the cases that continually occur here and there without any epidemic. It is probably the mild and unsuspected cases, of which there are many, and the recovered cases which are not yet free from the bacillus, from which these scattered cases become infected.

Flies may perhaps convey the germ of this as well as of other intestinal diseases to the food; for if there is any foul matter exposed anywhere in the neighborhood, the flies are sure to find it, and to pass from it to any food which they can get at; and thus food and filth which seem to be far apart may be mixed together by the agency of these pests.

The germ of cholera—a disease fortunately rare in Europe and America—is disseminated in much the same way as that of typhoid. The epidemics which have occurred in Europe have usually been traced to the water supply. The germs of dysentery and of the "summer complaint" of little children are transmitted in the

same ways. It is probable that flies have much to do with the prevalence of these diseases in the summer.

The germs of diphtheria are probably transmitted in about the same ways as those of tuberculosis; and the same is true of the germs of pneumonia, influenza and perhaps of cerebrospinal meningitis. It is a remarkable fact that the germ of pneumonia (the "pneumococcus") is found in the mouth and throat of a large proportion of healthy persons. As compared with the germs of many other diseases, it may be said to be almost universally present. The fact that the disease is not more common—though, as it is, it ranks probably next to tuberculosis as a cause of death in the United States—the fact that it is not still more common is due to the high degree of resistance which the bodys offers to it. It would seem that the pneumococcus does not have much chance unless the resistance of the body is lowered. Pneumonia often follows another disease, as typhoid fever, measles, influenza, or perhaps sometimes a common cold. Alcoholism also greatly predisposes to pneumonia, and so does old age, when the vitality of the body is low. Influenza or the "grippe" is usually so mild a disease that we are apt to laugh

at it; but it is really a matter of some concern, because it predisposes to many other worse troubles, such as pneumonia and inflammations of the ear and of the brain. No care is usually taken to avoid taking influenza or to avoid passing it on to others. It would be much better to regard one suffering with influenza as a person sick of an infectious disease, and to expect him to seclude himself till he had ceased coughing.

The path of entrance of the germs already mentioned is through the mouth or nose; but this is not the case in all diseases. In some the germ is introduced directly into the blood through the skin. This is the mode of entrance of the germs that give rise to the suppuration of wounds and to the presence of pus in the blood. It is also the way of entrance of the germs of hydrophobia, and of tetanus or lockjaw. Then there are many diseases in which the germs are introduced into the blood by the bite of an insect. The best known of these diseases are malaria, yellow fever, and the bubonic plague.

The facts regarding malaria are specially interesting. It had long been noticed that this disease was specially prevalent in certain localities, especially in the neighborhood of swamps. The disease was supposed to infest the locality

and to enter the system from the air, which was accordingly called "bad air," whence the name *malaria*. In 1880, however, it was discovered that the blood of malaria sufferers contained large numbers of a little organism belonging to the protozoa. The name given to this germ is *plasmodium*. It was observed to burrow its way into the red corpuscles of the blood—the oxygen-carriers, as will be recalled—and to feed on them, till it had consumed most of their substance, when it proceeded to divide into a considerable number—about sixteen, in the commonest form of malaria—of young plasmodia, which were then discharged into the blood, and proceeded to attach themselves each to a fresh red corpuscle and begin the process over again. The "chill" of malaria occurred when these numerous little creatures were discharged into the blood; and in the common type of malaria, in which the chill occurs every two days, this is the time needed by a parasite, which has entered a red corpuscle, to reach its full growth, divide, and discharge its progeny into the blood again.

The peculiar symptoms of malaria—the periodic chills and fever, and the weakness and anemia—were explained from the habits of the parasite. If this was what did the harm, it could

hardly be that the disease resided in the air; there must be some channel of infection. A period of twenty years elapsed before the channel of infection was discovered, and then it was found to be the mosquito. The mosquito, biting a person who has malaria, sucks into his stomach a number of the young plasmodia. It does not, however, on passing to another victim, pass some of these same plasmodia into his blood and so infect him. Something much more complicated happens. The little plasmodia proceed to develop in the mosquito's stomach, some of them becoming males and some females. The males and females unite, and the cells formed by their union penetrate the stomach wall of the mosquito, and, while embedded there, form within themselves numerous young ones, which enter the blood of the mosquito, and circulate through his body. Many of these get finally into the salivary glands of the mosquito, whence they are injected into the blood of any human being whom the mosquito may find to bite. About ten days are needed for this development to occur within the body of the mosquito, and this time therefore elapses between the infection of the mosquito by the malarious human being whom he first bit and the infection of another man

by the mosquito. Not all kinds of mosquitos afford a suitable nesting-place for the malaria parasite; the most common genus in the United States, the *culex* mosquito, does not convey the infection of malaria. It is the genus of mosquito called *anopheles* that does the business. This form can be most readily distinguished from the more common mosquito by the position which it assumes in biting. Whereas the ordinary mosquito keeps his body horizontal, or parallel to the skin on which he is standing, the anopheles stands with his body more nearly perpendicular to the skin, much in the position of a steam drill.

Since this mosquito is the means of transmitting malaria, the best way to combat the disease is to get rid of mosquitos. The best way to attack them is to destroy their breeding-places. The mosquito lays its eggs in still water, where the eggs first develop into little "wigglers," which swim about in the water till they reach a certain stage of development, when they rise from the surface and fly away. Covering the surface of a pond with a thin layer of petroleum makes it impossible for the young mosquito to rise from the water. Gold fish or minnows in the pond feed on the wigglers and keep their

numbers down. Draining off swamps and bodies of standing water, screening cisterns and water barrels, removing tin cans which may lie around, half full of water and affording a fine place for the wigglers—these measures prevent the breeding of the mosquito. Screening houses does a good deal to prevent mosquito bites. Screening the malaria patient so that no mosquitos can get at him makes it impossible for him to be a new center of infection; for the mosquito has no malaria to transmit unless he has bitten a man with the disease; and one man cannot transmit the disease to another except by the agency of a mosquito. Finally, quinine, taken in sufficient doses, kills the plasmodium in the blood, and may properly be taken, not only to cure an attack, but to ward it off where there has been exposure. With all these means at our command, it would seem that we were now in a position to deal intelligently and successfully with this disease, which though not highly fatal in temperate climates, causes an immense amount of discomfort, weakness and loss of time.

Yellow fever, too, has been shown to be transmitted from one man to another by a mosquito, though by a different kind than the one that

carries malaria; and this knowledge has enabled the authorities of New Orleans, Havana, and Panama to eradicate this much dreaded disease.

The "plague," which has appeared in European history at intervals for over two thousand years, which was known as the "Black Death" in the fourteenth century, when it spread over Europe and killed at least a quarter of the inhabitants, which again wrought great havoc in the seventeenth century, when, during the "plague year," 1665, it caused the death of nearly 70,000 of the inhabitants of London, has been so long absent from the countries of western Europe as to seem almost a thing of the past. It has, however, probably, never disappeared altogether from the face of the earth, but has kept up an existence in one or more remote places, such as upper Egypt, from which many of the epidemics of old times radiated, or as the interior of China, from which the Black Death seemed to originate, and which has recently harbored the disease. In 1893, the plague appeared in Canton and Hongkong, and from thence it has spread to India and Egypt, and in a small way, to many parts of the world. The western nations have successfully combatted its entrance, but in India and China it has been very destructive.

This renewed activity of the long dormant disease has given the opportunity for looking for the germ causing it, and for the manner of its transmission. The plague bacillus was quickly identified, and observation and experiment have established many facts regarding its transmission. The disease is one of rats as well as of men, and experiments on rats have shown that the means of transmission from one rat to another is by the agency of fleas, which desert a plague-stricken rat on its death, and find lodgment with another, to which they convey bacilli which they have extracted from the blood of the first. It has been shown, also, that these rat fleas do not despise human prey, and it seems likely that the principal means of the spread of the disease is from rats to man by the agency of fleas. Hence it is that those who live amongst vermin are most attacked by this disease, and this fact throws light on the conditions of life in the middle ages and down into quite recent centuries. The rats which often infest ships are believed to be the means by which the plague is so readily carried from one port to another. There is, however, another means of transmission from man to man, though this is not so frequent as the means already mentioned.

The disease sometimes takes a form resembling pneumonia, and is then probably transmitted directly from man to man by the minute droplets of mucus expelled into the air in coughing. Much success has attended the efforts to stamp out the disease by destroying rats. It has also been found possible to vaccinate against the plague, in India, with a high measure of success.

Besides the two paths of entrance of disease germs into the body which we have examined, the path through the mouth and nose, and the path through the skin by wounds or bites, there are still a few other entrances by which special sorts of germ find their way. A form of inflammation of the eye which is very common and highly contagious has been shown to be due to infection with a certain bacillus, which obtains a direct entrance to the eye by the use of dirty towels, previously used by an individual suffering from the inflammation. This seems to be especially common among school children, who may also pass the infection from one to another by lending handkerchiefs, pencils, etc., which have previously come into contact with their eyes, either directly or through the hands as intermediary. Let a hand rub an eye, and the next moment handle a pencil; then let the pencil

pass to the hands of another child, which hand soon afterwards goes to his eye—and we have a series of contacts which is capable of conveying germs from one eye to another.

Two other diseases, of great seriousness and widespread prevalence, gain an entrance through the sexual organs. These are gonorrhea and syphilis. The germ of gonorrhea is a coccus, called the gonococcus, and that of syphilis is a spirillum, to which the name of treponema pallidum has been given. The gonococcus attacks primarily the mucous membrane lining the urethra, whence it is likely to spread upwards to the bladder, and may also get into the blood and be spread widely through the body. The germ of syphilis penetrates the skin at the point of infection, where it forms a sore and multiplies, escaping thence to the blood and being spread all over the body. As the germ of syphilis must penetrate the skin to gain a foothold, it is not so easily transmitted from one individual to another as is the gonococcus. Yet the prevalence of syphilis among the population is very great and apparently increasing, while the prevalence of gonorrhea is astounding. Though it is hard to secure reliable statistics regarding this matter, it is probable that some-

thing like one half of the male population of Europe and America becomes, at one time or another, infected with this disease. Among those who practice promiscuous sexual intercourse, the proportion is much higher; in fact, one who continues long in such promiscuity is almost certain, sooner or later, to contract gonorrhea, and stands a very good chance indeed of contracting syphilis as well. The spread of these diseases is favored by ignorance regarding their prevalence, by recklessness in exposure to infection, by the often criminal indifference of those who have the disease as to whether they shall pass on the infection to others, and by the fact that, as we have seen above in the case of typhoid and other diseases, an individual who has apparently recovered from an attack may still harbor the germ and be capable of transmitting it. Even apart from all considerations of personal purity and morality, one should regard promiscuous sexual relations as a very serious menace to health.

The serious nature of gonorrheal disease is often not fully appreciated. It may cause a vast amount of trouble. The local infection is not only painful and disagreeable, but may result in permanent injury to the urethra. If the

germ gets into the blood it is apt to cause a distressing form of rheumatism. In the female, who often innocently receives the disease after marriage, the results may be most serious, and the children of an infected mother are apt to suffer from an eye disease, which is the cause of at least ten per cent, and according to some authorities twenty per cent of all blindness. Many a man has thus, in his heedlessness, done irreparable harm precisely where he would most desire to avoid it.

Syphilis is emphatically a "rotten" disease, and remains for a long period a bane to its possessor, even if, in the hands of a skilful physician, he escapes the worst of its consequences. These are many and extremely varied, since the parasite, carried by the blood, finds lodgment in many organs and works havoc there. Speedily fatal cases are not rare. The brain and spinal cord are specially susceptible to this disease and its consequences, and it is responsible for a very large share of all the insanity of the present day, as well as for many other diseases of the nervous system. Its effects on the children of a diseased person are very serious. A large share of women infected become sterile, and a very large share of all children of syphilitic parents inherit

the disease, and either die in infancy or have poor brains or bad organs of some sort. It is probably to syphilis that we have to attribute the dying out of the native populations in various parts of the world, when they are exposed to infection by white men of the rougher sort who come among them. The promiscuity of many of these primitive people causes a rapid spread of the disease among them, with resulting sterility. Those who know the facts regarding syphilis regard it as one of the worst enemies of the human race; and the individual who becomes acquainted with the facts should certainly, for hygienic as well as moral reasons, see to it that he is personally preserved from the infection, and that he does his part, as a good citizen, towards bringing about a more intelligent and rational attitude towards this class of diseases. Under no circumstances should an individual who has become infected with either of the great venereal diseases allow himself to marry without thorough assurance from a competent physician that all danger of his passing on the infection is over.

From considering the ways by which disease germs gain an entrance to the body, and by which they are passed on from one individual to an-

other, we can see the sort of precautions that need to be taken to prevent infection. The precautions differ, to be sure, for different germs; if they are transmitted in what the infected person coughs out, we must beware of his neighborhood; if they leave him in his excretions, we need to disinfect these and prevent all possibility of their contaminating food or water; if the germs are conveyed from one person to another by mosquitoes, we must get rid of them and especially keep them from the sick person. When any special disease is epidemic the special precautions needed are usually published by public health authorities; and with them must be left to a large extent the care of the milk and water and food supplies of great communities. The individual in a town is more or less helpless by himself, as he cannot get back to the sources of his supplies and examine into their cleanliness. This work of safeguarding the public health is more and more being taken up by nations, states and towns, and the man who gains an insight into the variety of the modes of transmission of disease, and of the value of scientific study in preventing disease, will not grudge the expenditure of public money on departments of health, but will realize that there is no econ-

omy so genuine as that which economizes human life and health. He who has learned a little about the need of preventing infection will, furthermore, be ready to lend his support to the measures and regulations which the health authorities endeavor to enforce.

As an example of the need of public authority for the prevention of the spread of disease we may take the efforts that are being put forth to safeguard the milk supply of cities. The milk industry of this country is for the most part still in a rather primitive condition. No great care is taken, in most dairy farms, to keep the milk absolutely clean and free from bacteria. The milk from a good farm is clean, of course, in the every-day sense that no noticeable amount of dirt is allowed to get into it. But to keep it clean in the modern, bacteriological sense, *i. e.*, to keep it free from bacteria, it would be necessary to sterilize the pails, the hands of the milkmen, and the teats of the cows, and to have the stable so free from dust that none could enter the pails. It has never been customary to be so "finicky" as this on the farm; and, indeed, even if all these precautions were taken, the milk would still not be entirely free from bacteria, as some are present even in the udder of the cow. But a few,

or a few millions, of ordinary barnyard bacteria in a quart of milk do no harm; and fresh milk, on the farm, is in ordinary conditions distinctly good.

Since, however, bacteria multiply very rapidly, unless destroyed by heat or kept dormant by cold, it comes about that in the twenty-four hours or more that often elapse between the milking and the use of the milk by the city family, the bacteria have increased to incredible numbers, and perhaps have turned the milk sour, or at least have deprived it of its freshness and made it unfit for use. The rate of increase of bacteria in milk can be gathered from the counts that have been made by the authorities of some of the large cities. When the milking has been done with great attention to cleanliness, the fresh milk starts with perhaps 2,500 bacteria per cubic centimeter (this being about 1-1000 of a quart). If this milk is chilled as soon as milked, and kept constantly on ice for twenty-four hours, there is very little increase in the bacteria during this time; but if the milk is allowed to stay lukewarm, the 2,500 increase within a day to nearly half a million per cubic centimeter.

As usually obtained at the farm, however,

the milk contains, when perfectly fresh, at least 30,000 bacteria per cubic centimeter; these, too, remain dormant for a day when the milk is kept very cold but increase very rapidly if the milk is lukewarm, so that, at the end of the day, there are likely to be 5,000,000 bacteria per cubic centimeter. Even this number does not necessarily make the milk dangerous to the health of adults, but it is distinctly bad for children. The efforts of the health authorities are being directed to securing as clean milk as possible at the farm, to keeping it cold all the time till it is delivered to the consumer, and to preventing any contamination in its journey from the farm to the consumer. Some cities have now made it unlawful to sell milk that contains more than 100,000 bacteria per cubic centimeter, or some other figure. "Pasteurizing" milk—which means heating it, not to boiling, but to a temperature of 140° Fahrenheit, and keeping it there for twenty minutes—kills the bacteria, but does not, of course, restore milk that has already gone bad.

Though much of the care for preventing the spread of disease must be left to public health authorities, and though much again must be left to the physician with his special knowledge, there are a few simple precautions which the pub-

lic generally can take. The old rules of cleanliness of the good housewife and of the cleanly person gain new significance from the modern science of infection. The keeping of food away from dust and flies, the use of the ice box, and the serving of freshly cooked meat and vegetables are very valuable precautions, especially in hot weather, and in the presence of any disease. The avoidance of common drinking cups and of dirty towels is to be strongly recommended.

Immediate attention to cuts of the skin, even slight ones, is a measure which every one should take. If a cut is allowed to go untreated, the bacteria that produce pus are practically sure to grow there, and the cut heals slowly. Moreover, the pus or the bacteria that cause it quite frequently pass from the cut along the lymphatic vessels in the skin and beneath it, and infect neighboring spaces lying quite under the skin, causing abscesses, which are not only disagreeable to deal with, but are likely to pass the infection still further along and cause blood poisoning. Moreover, a cut in the skin, if unprotected, may admit germs of very dangerous sorts and give rise to serious trouble. The skin is the body's defence against bacterial invasion, and where

the skin is cut or broken, the defences are down, and the invader, if he happens to find the spot, gains a ready entrance. It is not much trouble to attend to a slight cut so as to make it heal quickly, and so as to avoid suppuration and the possible invasion of disease. First wash out the wound, then apply an antiseptic, then cover the wound with a sterile cloth. There are many antiseptics which will do the business. Alcohol is a good one; but perhaps there is none better or more convenient than peroxide of hydrogen, the oxygen liberated from which destroys bacteria that have entered the wound. Peroxide, should, however, be fresh, as it deteriorates with long standing. If it causes foam to appear in the wound, this is a sign that the peroxide is good, and that it is finding something to destroy. A clean cloth may be made sterile by heat, as by ironing with a hot iron; but it is easy now to be provided with a small roll of sterilized gauze ready for use. Nothing that is not sterile should be allowed to touch a wound, or to pierce the skin, as in removing a splinter. The point of a knife or of a needle can be easily sterilized by holding it for a few instants in or over a flame.

Since the mouth is a common entrance for the germs of disease, it is worthy of some care in

the direction of minimizing the chances of infection. The mouth is a favorite home for many bacteria, and not infrequently for the germs of diseases, like pneumonia. Bacteria in the mouth, feeding on the teeth, cause their decay. This can be prevented in large measure by keeping the teeth clean. The brush used to free the teeth from particles of food should be so made as to have some power of penetration into the spaces between the teeth; and a little thought will show that an up-and-down movement of the brush is better suited to remove particles from between the teeth than a side-to-side movement. Besides freeing the teeth from bits of food it is necessary to use some antiseptic to kill the bacteria. The better tooth powders, pastes and washes contain antiseptics of more or less strength, which are at the same time not dangerous to take into the mouth. Nothing, perhaps, is better for the teeth than peroxide of hydrogen, which has been mentioned above as a very convenient thing to use on cuts in the skin. Since the peroxide is also a good mouthwash, for the purpose of keeping down the bacterial population of the mouth, and is besides a good gargle for sore throat, it is all in all a very useful toilet article; and the danger of its deterioration will be removed if it finds

considerable use, since then a new bottle will be bought before the solution in the old bottle has lost its power.

The nose, as well as the mouth, may sometimes to advantage be washed out with an antiseptic solution. Colds in the head are sometimes staved off in this way. But it must not be done roughly; special solutions which will not injure the delicate mucous membrane of the nose are to be used, and they should not be used cold. Some knowledge is also necessary in order to introduce the solution properly, and one who is to do it should be shown by a physician. More harm than good is often done by rash or unskilful syringing of the nose.

The sort of damage that is done the body by microbes which have gained entrance is very different according to the kind of microbe. The germ of pneumonia multiplies in the lungs till it makes them useless for supplying air and removing carbon dioxide; it kills by suffocation. The malarial parasite devours the red cells of the blood, and so lessens the power of the blood to carry oxygen to the organs. The tubercle bacillus, when it settles in the lungs, consumes them; it may also attack other organs, such as

the kidney, and devour their working cells. The bacillus of diphtheria acts in quite a different way, for the great damage which it inflicts comes from a poison produced in its growth and absorbed into the blood from the throat. The bacillus of lockjaw finds its way, from the wound where it enters, along the motor nerve fibers to the spinal cord and brain and poisons them in much the same way as strychnine does.

The body by no means remains passive when disease germs have gained entrance to it. In fact, one of the most wonderful powers of the body, which we are only beginning to understand, is its power of taking up arms against the invaders. It has a variety of means of defence. The fever, which usually goes with infectious diseases, is probably in some way a means of defense, though its exact use is not certainly known. The fever temperature is not usually high enough to kill bacteria. One effect of the high temperature is to make the blood more fluid —less sticky or "viscous"—and so to make it easier for the heart to pump it around with great rapidity; the heart does this, as is shown by the strong and rapid beat in fever. The rapid circulation may be similar to the mobilization of forces in war; that is, it may bring the agents of the

body which can destroy the bacteria more quickly against them. Among the soldiers of the body in its fight with the invaders are the white cells of the blood. When bacteria have got into the body, as for example in a wound, the white cells gather there in great numbers, and eat up the bacteria. Many of the white cells are themselves destroyed in the conflict, and their dead bodies are found in the pus which appears in the wound.

But there is a still more remarkable way in which the forces of the body do battle with the germs of disease. Not only do the white cells bodily devour the bacteria, but somewhere in the body, perhaps in these same white cells of the blood, perhaps in the cells of various organs, are produced fluids which have the power of breaking up the bacteria, dissolving them, and so preventing their multiplication. And when, as often, the bacteria do damage, not so much by their great numbers as by the poisons which they produce, the body produces substances which neutralize these poisons and take away their power of doing harm. Since the poisons of the bacteria are called, in scientific language, *toxins*, the substances produced by the body which neutralize the poisons are called *antitoxins*.

The poisons of the various bacteria are different, and, to correspond, the body has the power of producing various antitoxins. Even before the disease germs enter, the body has in it a small quantity of various antitoxins, and is able promptly to destroy a few of the invaders, or to neutralize a small amount of their poison. But if the bacteria continue to multiply in the body, or to throw out their poison into the blood, the body is stimulated to produce more and more of the antitoxin. This is the kind of war that goes on in the body attacked by diphtheria or typhoid fever; the bacteria multiply and pour out poison into the blood; the body reacts by forming antitoxin; the invading bacteria, on their side, are stimulated to produce more poison; and the body still responds by increasing its antitoxin. Which of the opposing forces shall gain the victory depends on their comparative reserve powers. Some bodies can bring to bear much more powerful reserves of antitoxin, and can better stand the severe strain which the conflict puts on the general endurance of the system. Also some breeds or "strains" of typhoid bacilli have much more poison-forming power than others, as we recognize when we say that one person is attacked with a mild form of the disease and an-

other with a severe form. If the body finally gains the advantage, and the crisis of the fever is successfully passed, this means that the antitoxin-forming powers of the body have proved superior to the toxin-forming powers of the invading bacteria.

The blood of a man or animal undergoing an infectious disease has great power of neutralizing the poison of that disease, or, in other cases, great power of destroying the bacteria of that disease. This power does not usually depart at once when the disease is recovered from, but persists for a time, so that if a fresh invasion of the same sort of bacteria occurs, the body is well prepared for them, and at once destroys them or neutralizes their poisons, and does not contract the disease a second time. We say that the man is *immune* to that disease. Immunity is specific; that is, it does not extend to other diseases, for their bacteria and poisons are different, and the resisting powers of the body have been developed only for the particular disease. Thus, one who is getting over the measles can easily catch scarlet fever, but not the measles again. This immunity lasts for a variable time. For some diseases, as smallpox and yellow fever, it lasts for years, and more or less for life; for

other diseases, it lasts but a few months; and for some, it lasts scarcely at all. Its lasting powers vary also in different individuals.

All of this seems highly mysterious and almost uncanny, but is well established as a matter of fact. About the only attempt at explanation that has received much favor runs somewhat as follows. The poison produced by the bacteria could not harm the living cells of the body if it remained entirely outside them. It must get into union with them, and this could only be if the substance of the cells had an attraction, or chemical affinity, for the poison (just as oxygen cannot burn glass, there being no affinity between them). Now, as the chemical constitution of living matter is very complex, it may be that this affinity is not between the poison and the living matter as a whole; it may be rather that a certain *part* of the living matter has an attraction for the poison, and combines with it. After combining with the poison, this part of the living matter may break away from the rest of the cell substance, and, passing into the blood, be excreted as waste matter, carrying the poison with it. But this removal of a part of itself may stimulate the cell to make more parts like the part that has gone, and it may even be stim-

ulated to produce them in abundance, discharging them into the blood, where they would unite each with a little of the bacterial poison, and so neutralize it, protecting the cells from further attack and eventually carrying the poison out of the body. Some of these parts of cells would remain in the blood after the disease had been thrown off, and so protect against a fresh invasion of the same bacteria. But since the poisons of different bacteria are chemically different from one another, the parts of the living substance for which they have an affinity would differ, and the parts developed in reaction to the bacteria would differ, so that, as said above, the immunity would hold only for the disease which had been undergone.

From the facts we get a correct conception of the *cure* of an infectious fever. The body itself performs the cure, by producing substances which kill the bacteria or neutralize their poison. The body itself produces the medicines which are suited to the disease. The medicines which the physician gives play usually a minor rôle, serving to keep up the general strength under the severe strain which is imposed on the body. Hence, at the present day, more stress is laid on good nursing, in such a disease as typhoid fever,

than on drugs. Only in a few instances do we know of drugs that, when taken into the body, act directly to destroy the bacteria or neutralize their poison. Quinine has the power of destroying the malarial parasite, and this is especially fortunate, as the body does not seem to have great powers of resistance to this enemy; it does not, promptly at least, develop an antitoxin against malaria, and therefore is much helped by quinine. When disease germs have attacked a wound in the skin, or any easily accessible part of the mucous membrane, we can help the body in its fight by the use of antiseptics, as has been said a few pages back. For most of the infectious diseases, we do not know of any drugs which can be used to take the place of the antitoxin developed by the body itself. But since an animal which has a disease develops in its blood large amounts of the antitoxin for that disease, introducing the blood of such an animal into another animal makes the second animal immune to the disease, at least for a short time. This is the basis of the modern "serum treatment" of a number of diseases, "serum" being blood with the red and white corpuscles filtered out.

The serum treatment of diphtheria is best

known. A horse is made to develop large quantities of diphtheria antitoxin. This is done in the following manner: First the horse is made to contract a mild form of the disease. He responds to this by developing some antitoxin, and throws off this mild attack with ease; the antitoxin which he has developed now makes him capable of resisting a more severe form of the disease, and in resisting this he develops still more antitoxin, till finally he is able, without becoming ill himself, to withstand the most severe attack of the diphtheria germ. When he has reached this condition, his blood is very strong in the antitoxin. Some of his blood is then drawn off, freed from its cells, tested, standardized and sterilized, and put up in suitable form for distribution. A little of this serum, with the strong diphtheria antitoxin which it contains, will, if introduced into the circulation of a human being attacked by diphtheria, neutralize a great deal of the diphtheria poison, and so aid the body in its fight with the disease. The horse, having developed strong defences against this particular enemy, becomes the efficient ally of the human body in its fight; in fact, the same horse may become the ally of many human beings. The horse has never been so much the

friend-in-need of man as in the fight against diphtheria.

This recently discovered antitoxin treatment differs in some respects from vaccination, which has long been known as a means of preventing smallpox, but the two modes of treatment have much in common. In the antitoxin treatment, the body receives the antitoxin, ready-made, from some other animal; in the vaccination treatment, the body is made to develop its own antitoxin by contracting a mild form of the disease, after which it is able to resist a severe form. It has long been known that some epidemics of typhoid were mild, and others severe; and the same of epidemics of other diseases. Sometimes it has been thought wise to expose a person to a disease in a mild form, so as to render him immune against more severe epidemics that might come later. This was long recognized as a good way of dealing with smallpox. Then it was noticed that cattle are subject to a disease similar to the smallpox, but much milder, and that human beings sometimes caught this mild disease from cattle, and were then immune to smallpox. This observation—made by Jenner, an English physician, in the year 1796—led to the practice of infecting human beings with cowpox, or "vac-

cinating" them. The theory of this was not well understood, but the practice was found to work well—so well, indeed, that in a hundred years, smallpox became a rare disease, instead of being, as it had been, one of the most common and deadly of all diseases. The theory of vaccination, as now understood, is that cow-pox is due, probably, to the same germs as smallpox. The two diseases are really the same. But the cow has naturally great powers of resisting this germ. It reacts promptly to the germ, and renders it comparatively weak and harmless, so that human beings, who have small powers of resistance to this germ in its strong condition, are able to resist the weakened form of it which they receive from the cow. In reacting to this weakened form, they, however, develop their own powers of resistance—their antitoxic or their germ-destroying substances—and so are able, later, to resist the attacks of the germ in its strong state.

It is now known that the "virulence," or disease-producing power, of any sort of germ can be weakened by introducing it into the body of an animal which has strong powers of resistance, or by growing it at a temperature which is unfavorable to it. By use of such devices, it has lately been found possible to extend the principle

of vaccination to other diseases, such as the plague and cholera, and several diseases of animals. There are many difficulties to be overcome, many complicating conditions to be understood, before the principle can be extended to all diseases; but there seems good reason to hope that further experiment and increasing knowledge will finally make it possible to protect the community against all the dreaded infectious diseases, either by rendering those who are likely to be exposed immune before they are exposed, or by aiding them, after exposure, by the introduction of antitoxins from outside.

Many people are frightened or depressed when they first learn of bacteria and disease germs. Danger seems to lurk on every hand, invisible and intangible. They may even wish that science had not discovered these germs. They forget that the germs have always been there, and that knowledge of their presence and ways does not make them any worse, but quite the contrary, since we can now deal intelligently with them. The attitude of the scientific student is one of hope. He believes that we shall be able to get the mastery of disease germs, and to eliminate infectious diseases from among the causes of sickness and death. The precautions to be

taken by the individual are not many nor difficult. We do not need to devote much time to guarding ourselves against infection. A few simple precautions, which are along the line of cleanly habits, are about all that are required of the individual. But communities must rouse themselves to do a great deal. The health of the individual can best be guarded by guarding the health of the community. Already the most progressive nations and cities have made great strides, and lowered the death rate considerably.

The individual, besides taking reasonable precautions against infection, can do much by keeping himself in vigorous health, so keeping up his powers of withstanding any disease, should it chance to attack him. Some individuals have naturally much greater powers of resisting disease than others, but any one, when in good health, is much more able to resist attack than when "run down" and in poor condition. Neglect of minor ailments, like colds, influenza, constipation, and even, perhaps, decayed teeth or suppurating cuts, makes one somewhat more attackable by disease germs, if any happen to come around. Alcoholism, by weakening the general condition of the body, makes a person more easily attacked. Habitual overeating has a little of the

same effect. Lack of sleep, excessive fatigue do the same; and so, on the other hand, do excessive indolence, excessive fat, lack of exercise. In short, most of the things to be done by the individual to fortify himself against disease are the very things that make for his general health and well-being.

INDEX